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Nakafuji et al.

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(54) **IMAGE FORMING APPARATUS**

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G03G 15/20 (2006.01)

(52) **U.S. Cl.** **399/307**; 399/148; 399/308

(58) **Field of Classification Search** 399/307, 399/308, 148

See application file for complete search history.

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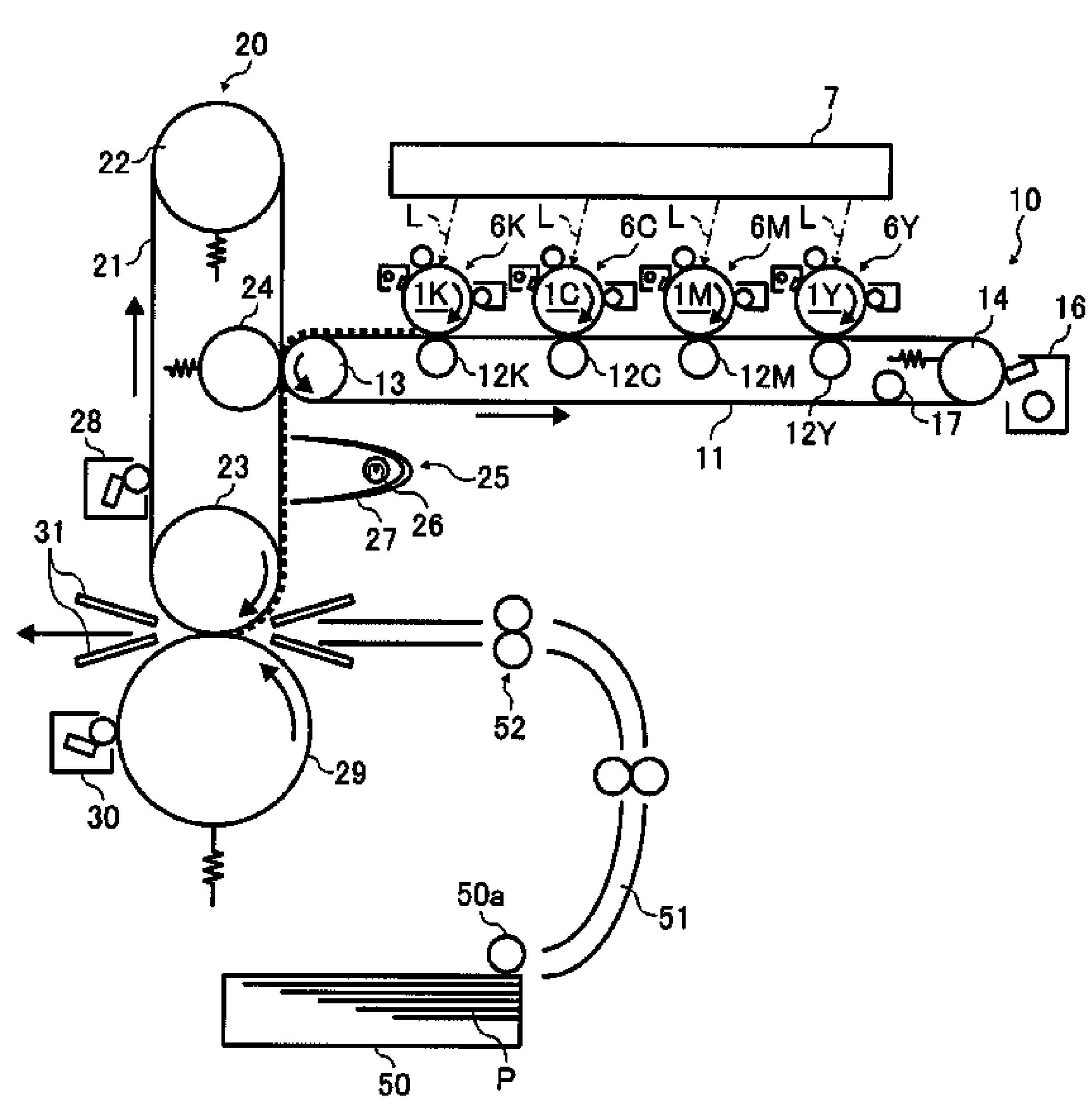
(57) **ABSTRACT**

An image forming apparatus includes an image carrier for bearing a visible image thereon, an endless transfer-fixing belt stretchedly disposed between a plurality of spanning members, a pressure member for pressing the transfer-fixing belt to the image carrier while contacting a backside of the transfer-fixing belt at the transfer nip, and a heater for heating the visible image. The visible image on the image carrier is transferred onto the front surface of the transfer-fixing belt at the transfer nip and is transported to the transfer-fixing nip while heated by the heater, where the visible image is transferred and fixed on a recording member. The transfer-fixing belt is stretchedly arranged such that the transfer-fixing belt travels in a direction substantially perpendicular to a pressure direction of the pressure member in the proximity of the transfer nip.

7 Claims, 7 Drawing Sheets



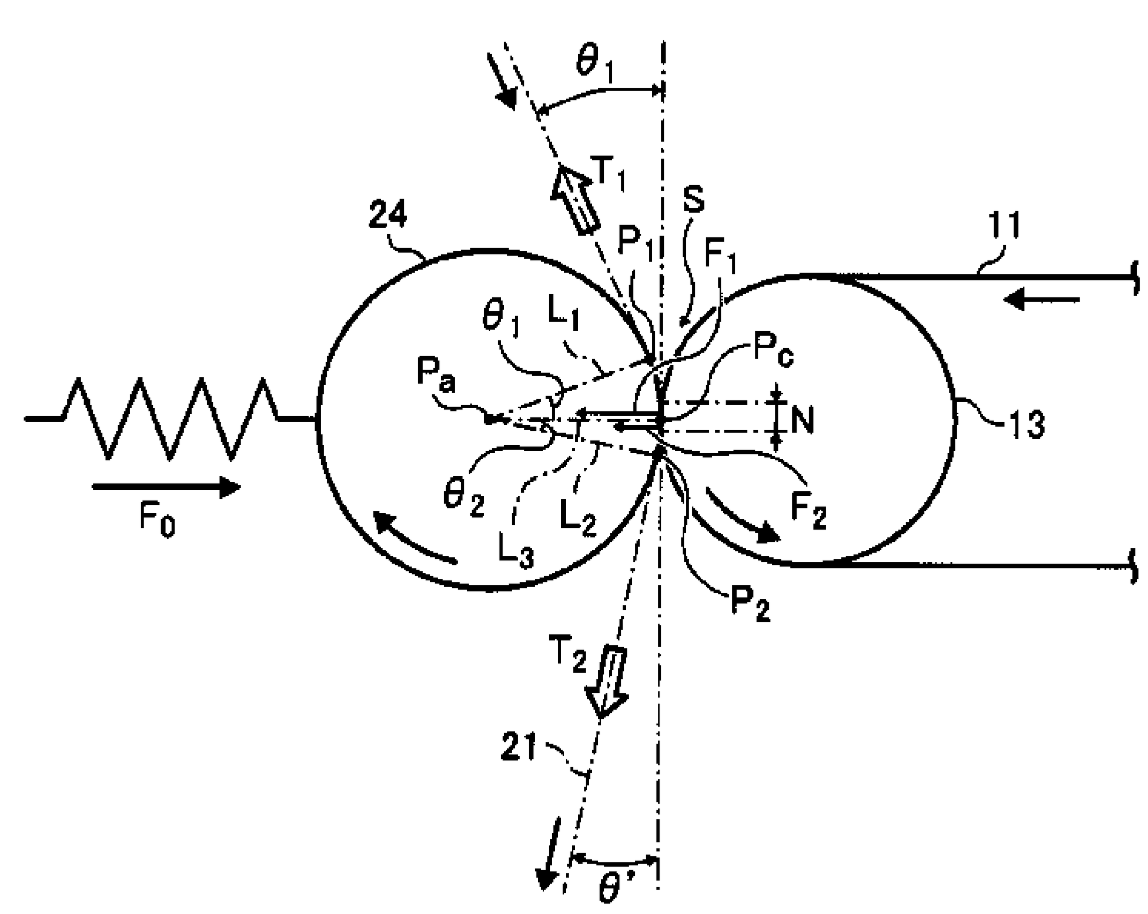


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FIG. 1
BACKGROUND ART

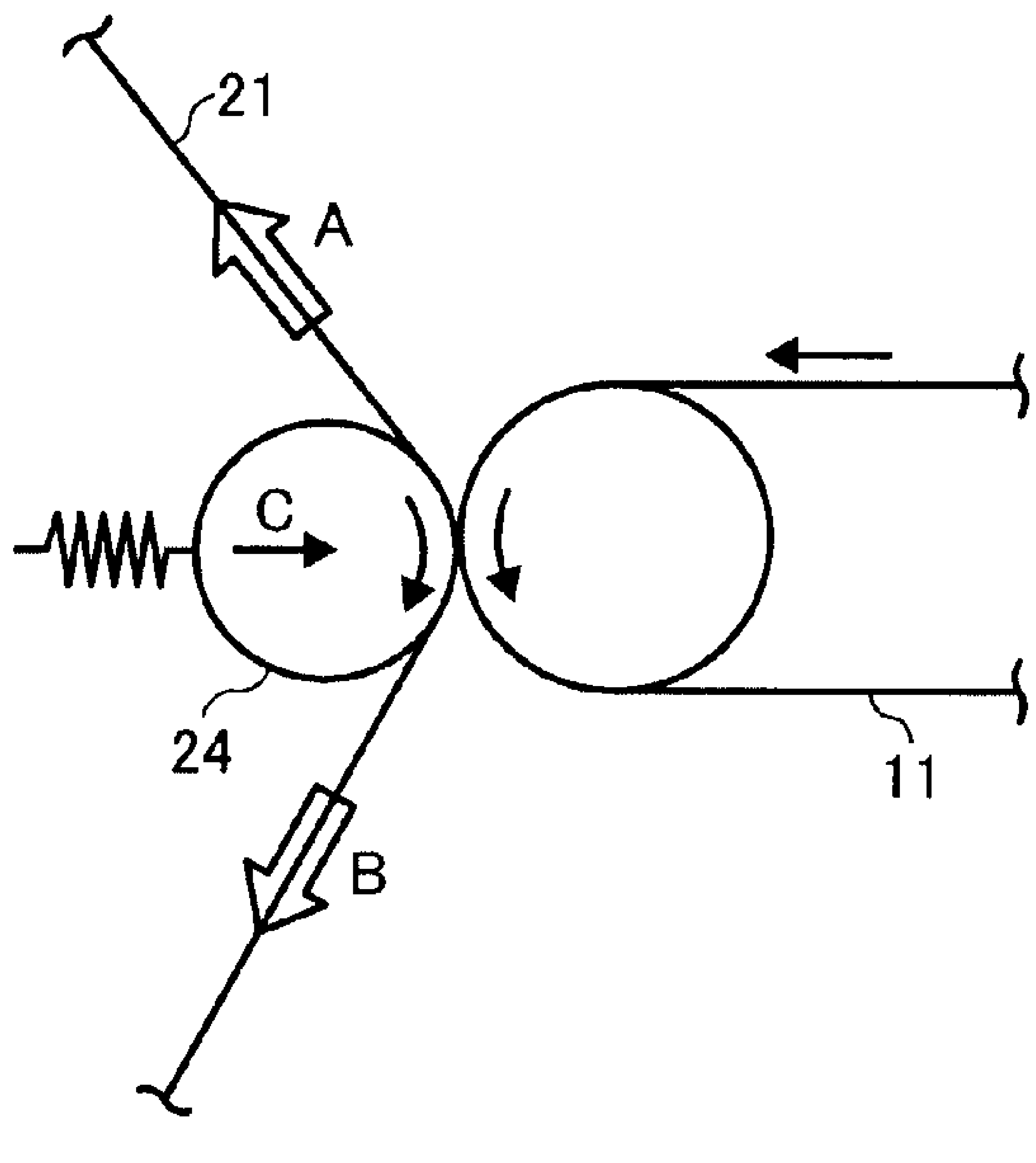


FIG. 2

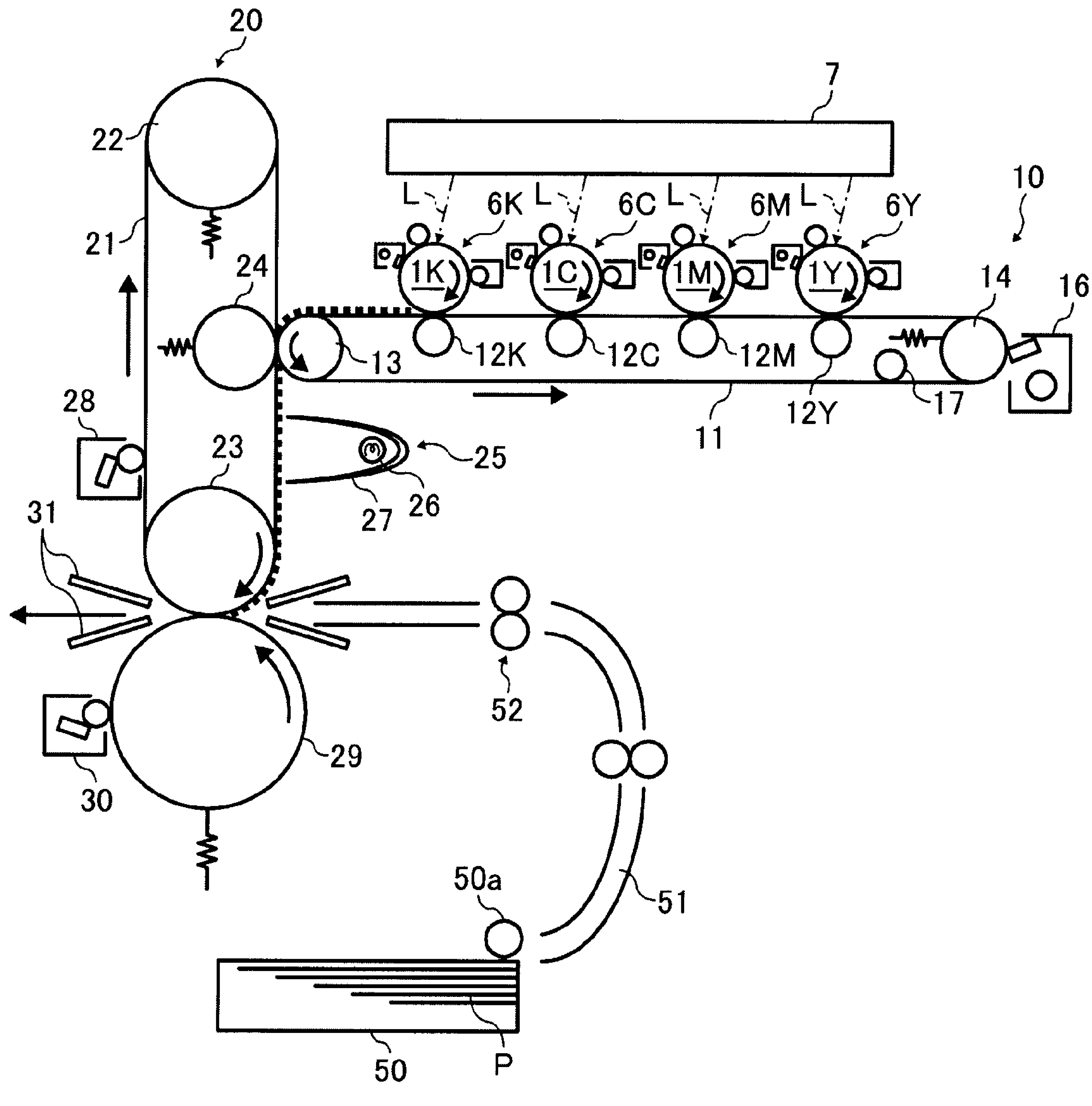

20
7
22
10
21
L
6K
6C
6M
6Y
1K
1C
1M
1Y
24
14
16
13
12K
12C
12M
28
11
12Y
17
23
25
26
27
31
52
29
30
50a
51
50
P

FIG. 3

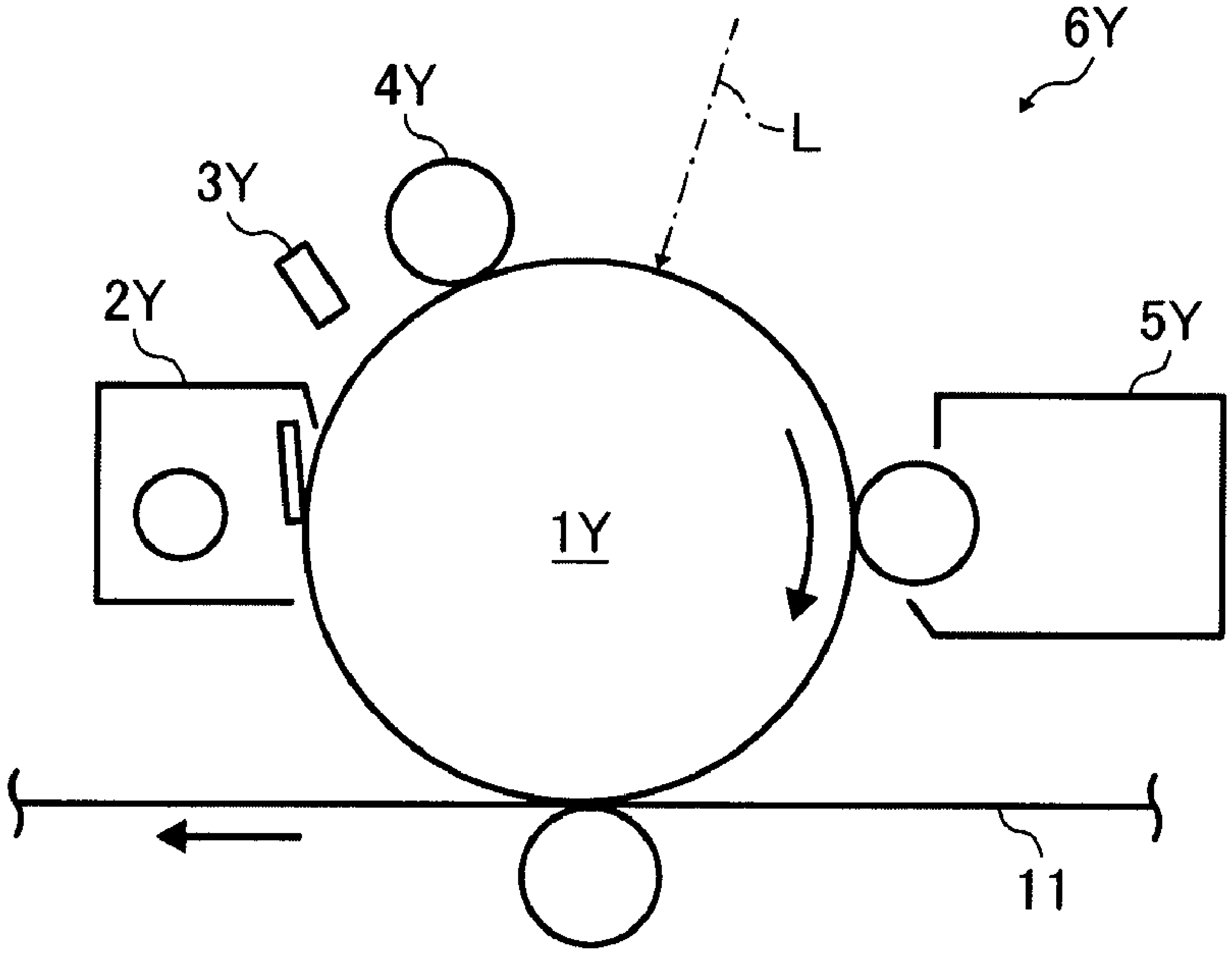

6Y
4Y
L
3Y
2Y
5Y
1Y
11

FIG. 4

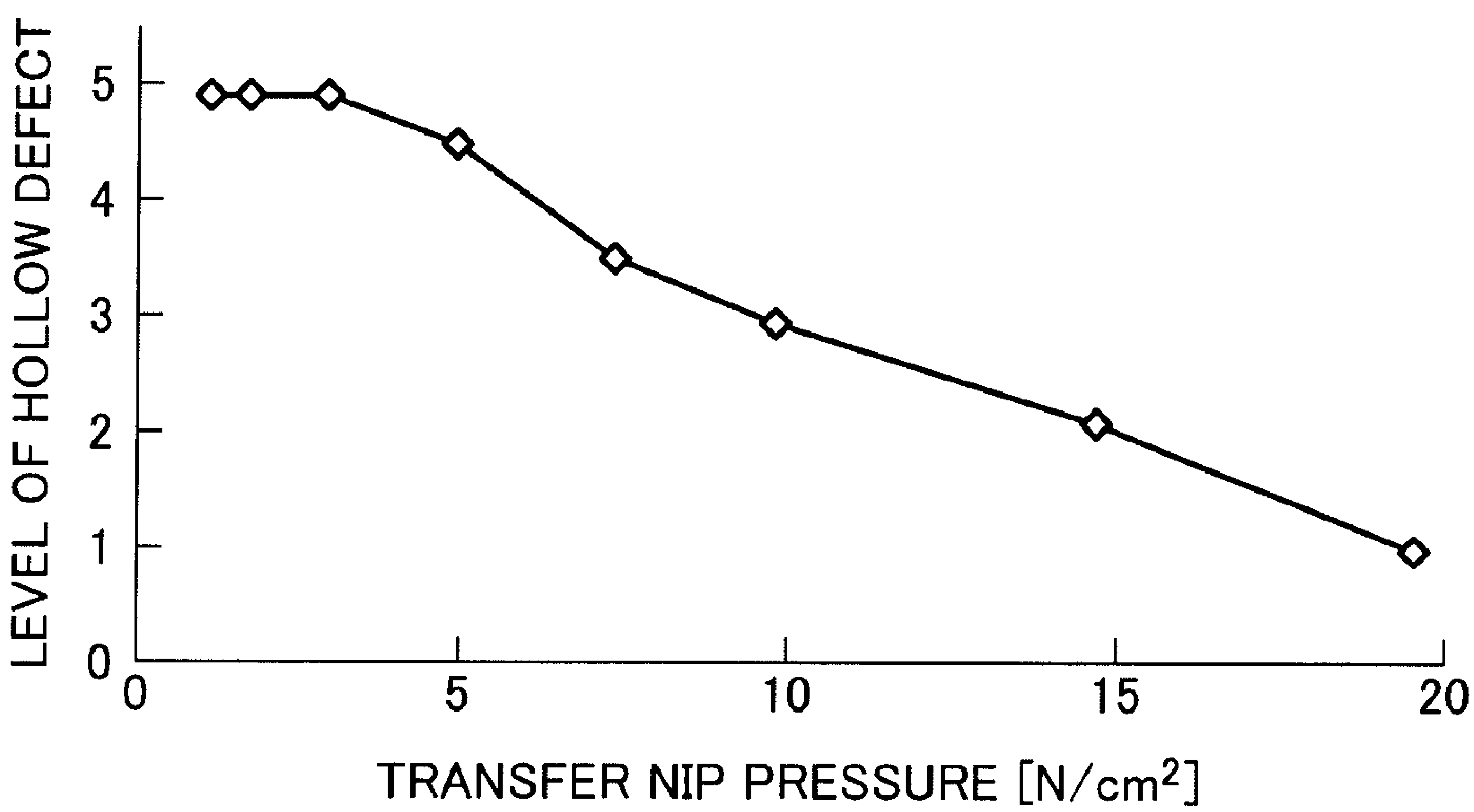

LEVEL OF HOLLOW DEFECT
5
4
3
2
1
0
0
5
10
15
20
TRANSFER NIP PRESSURE [N/cm2]

FIG. 5

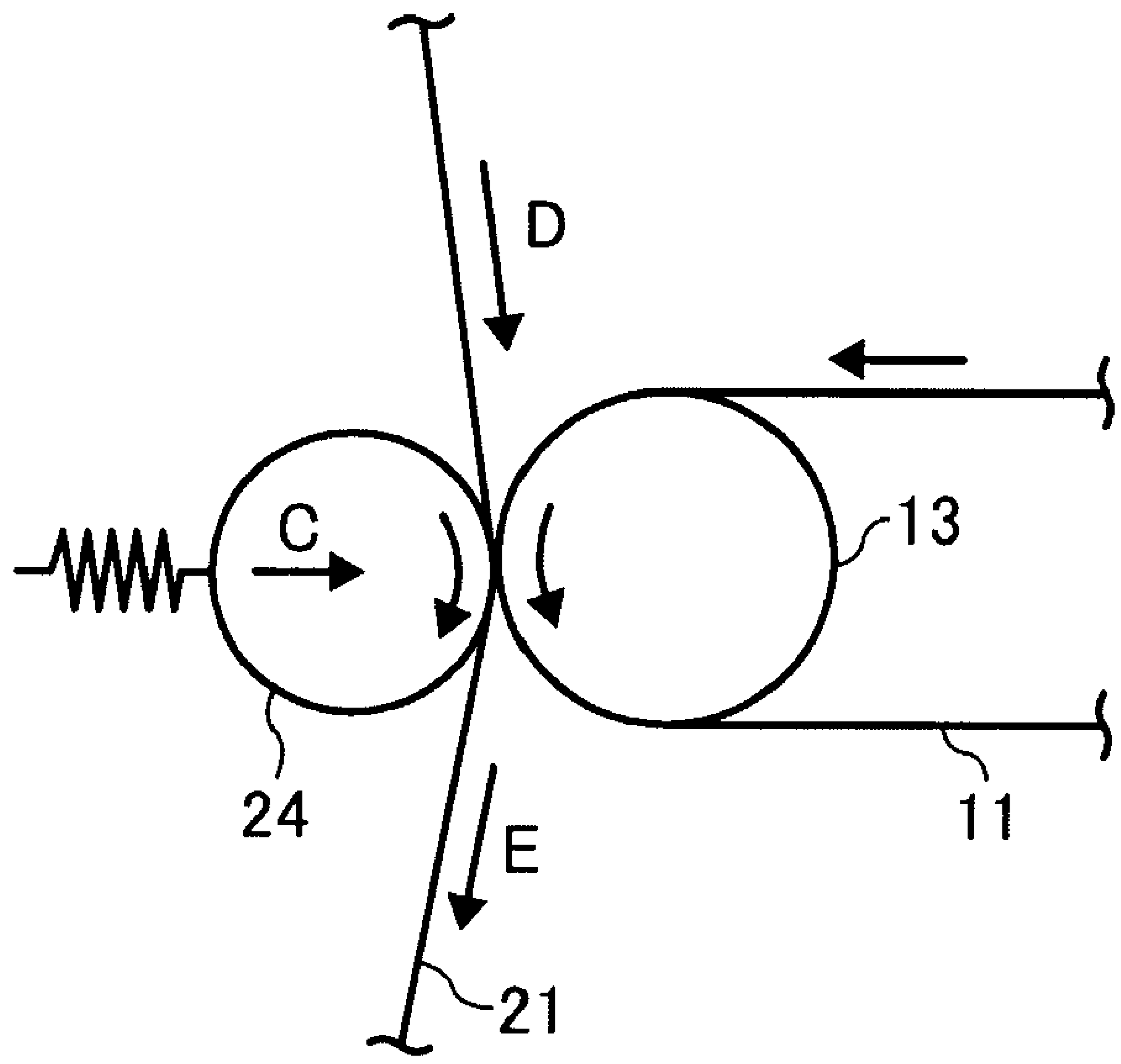

D
C
13
24
11
E
21

FIG. 6

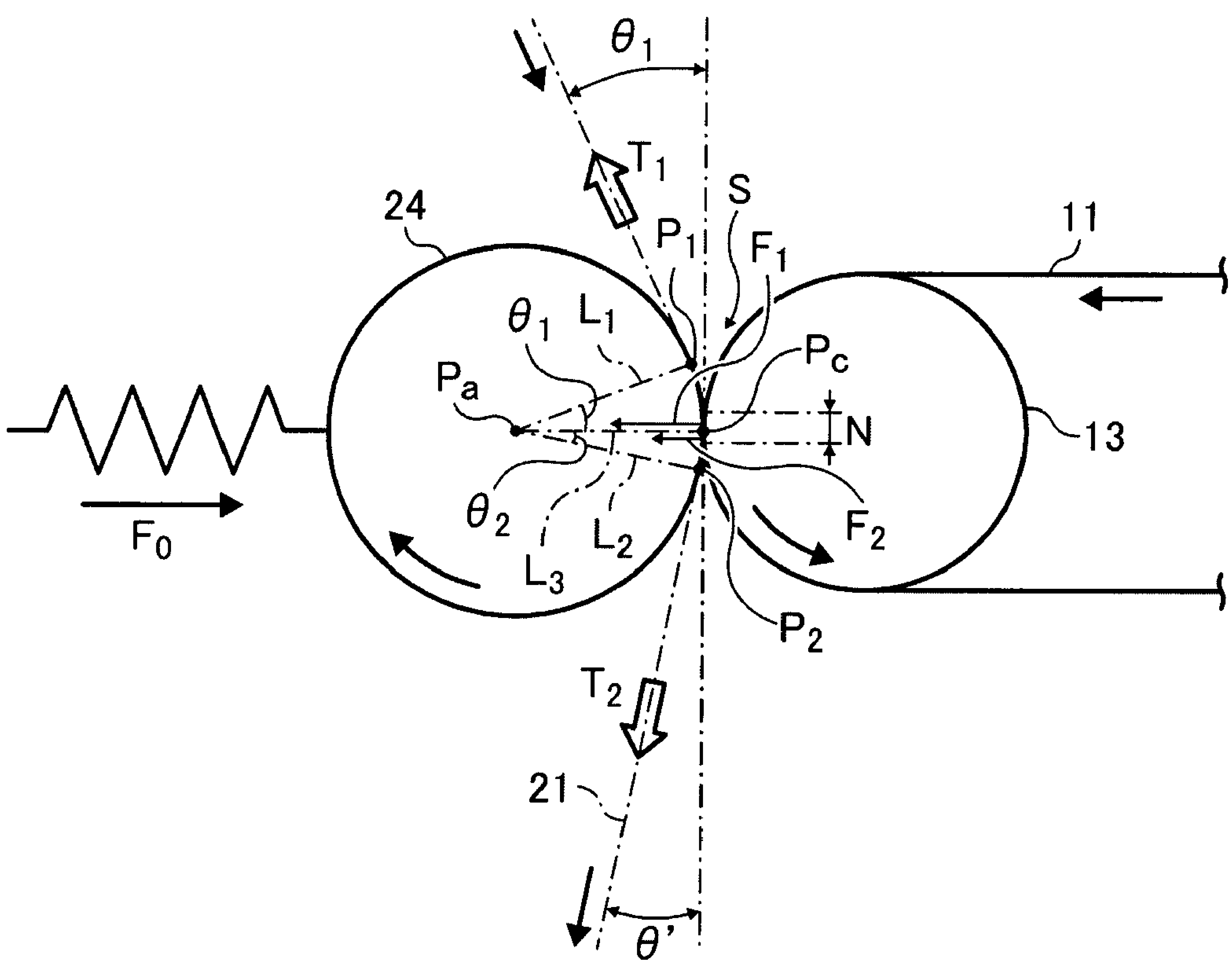

θ1
T1
S
24
11
P1
F1
θ1
L1
Pc
Pa
N
13
F0
θ2
L3
L2
F2
P2
T2
21
θ'

FIG. 7

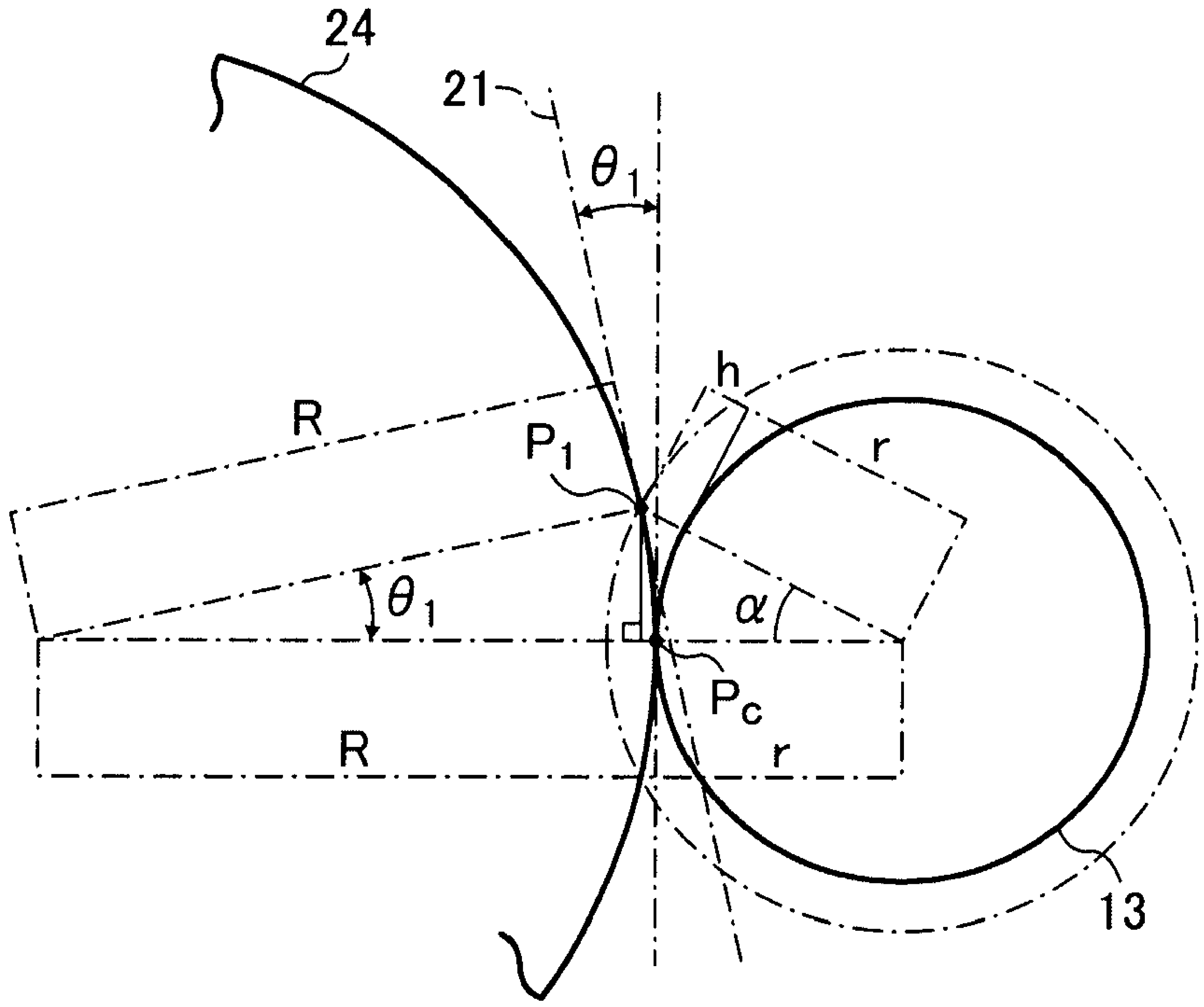


FIG. 8

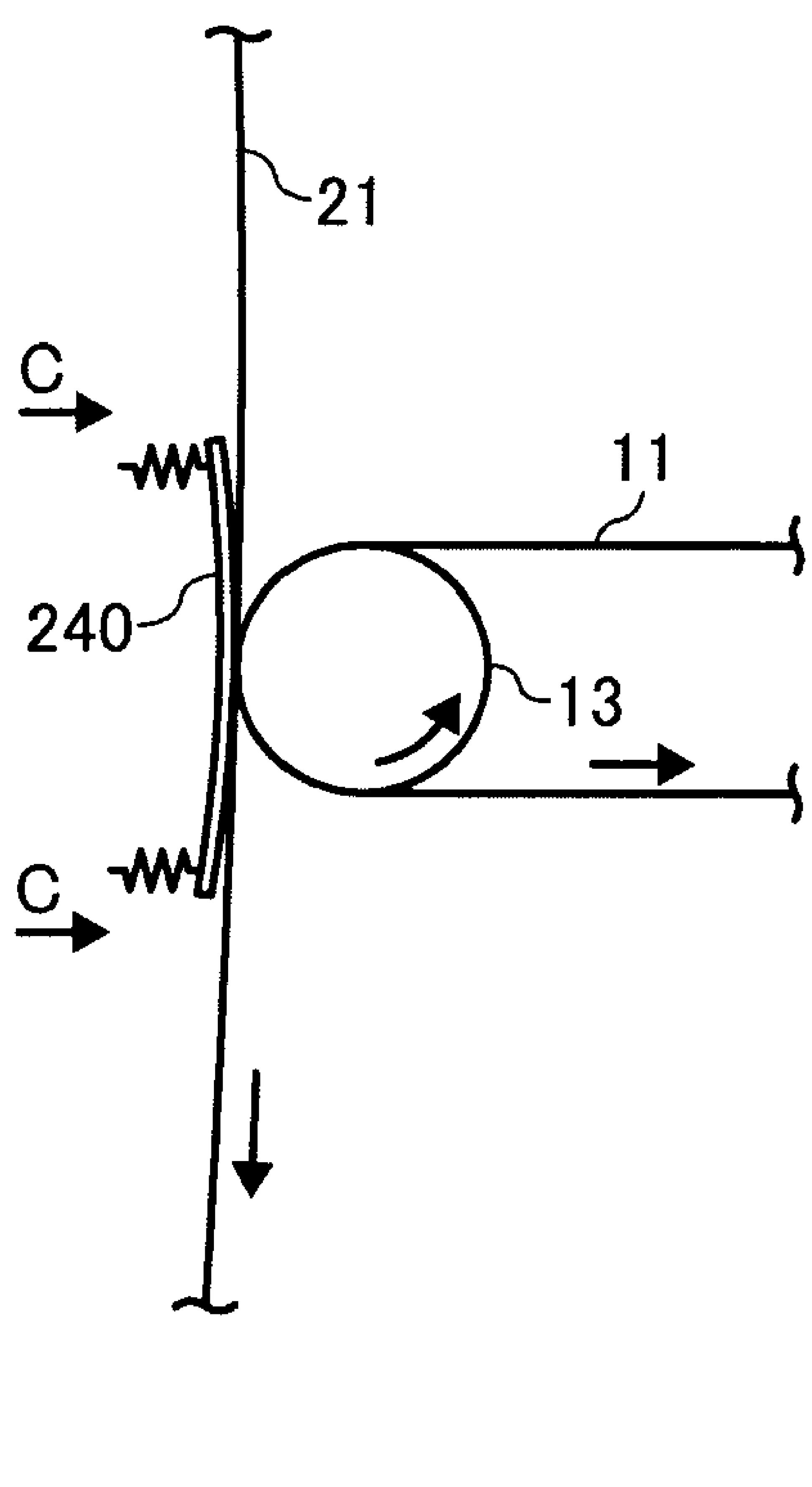
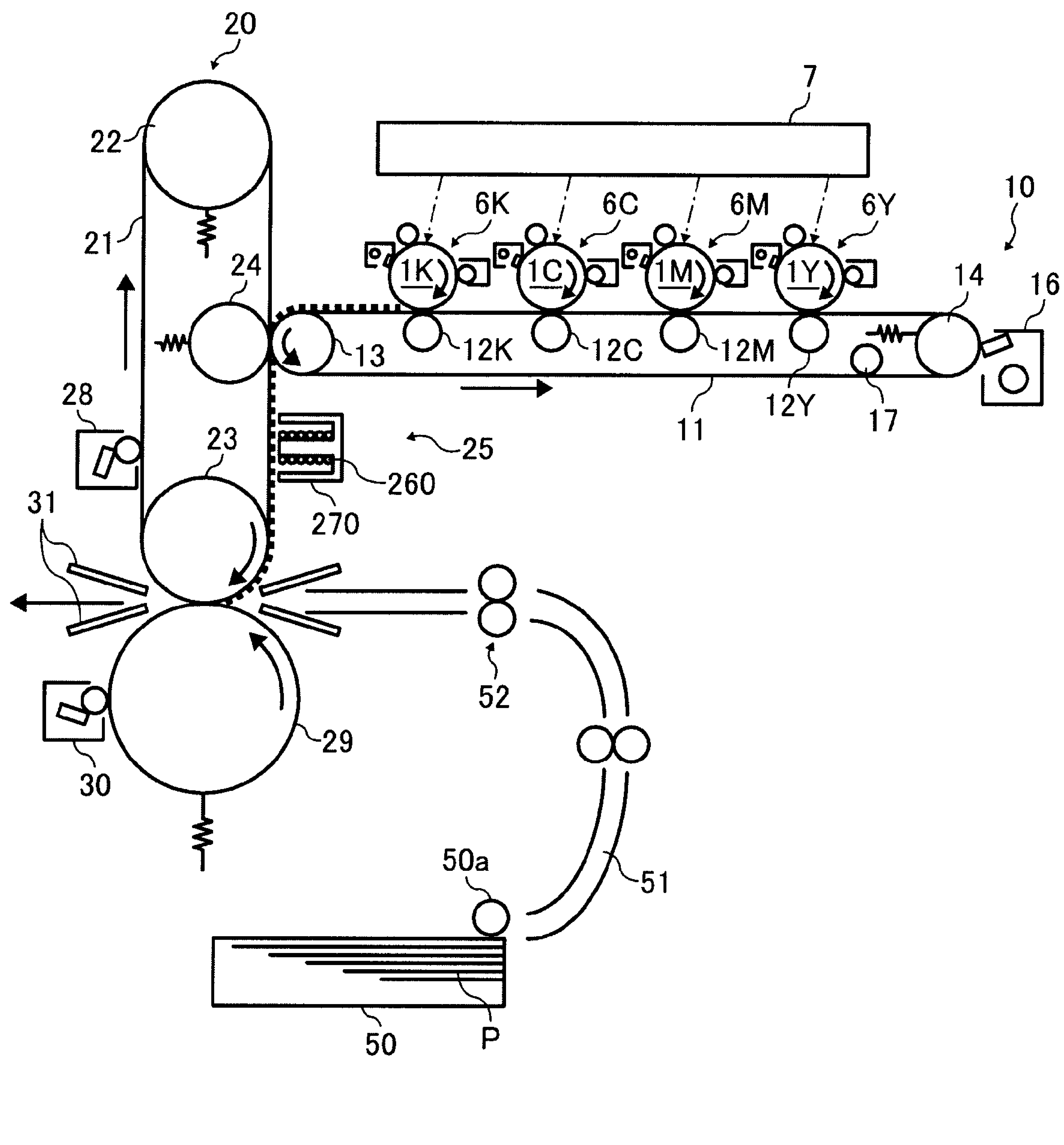


FIG. 9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6C
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6Y
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1Y
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12C
12M
12Y
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25
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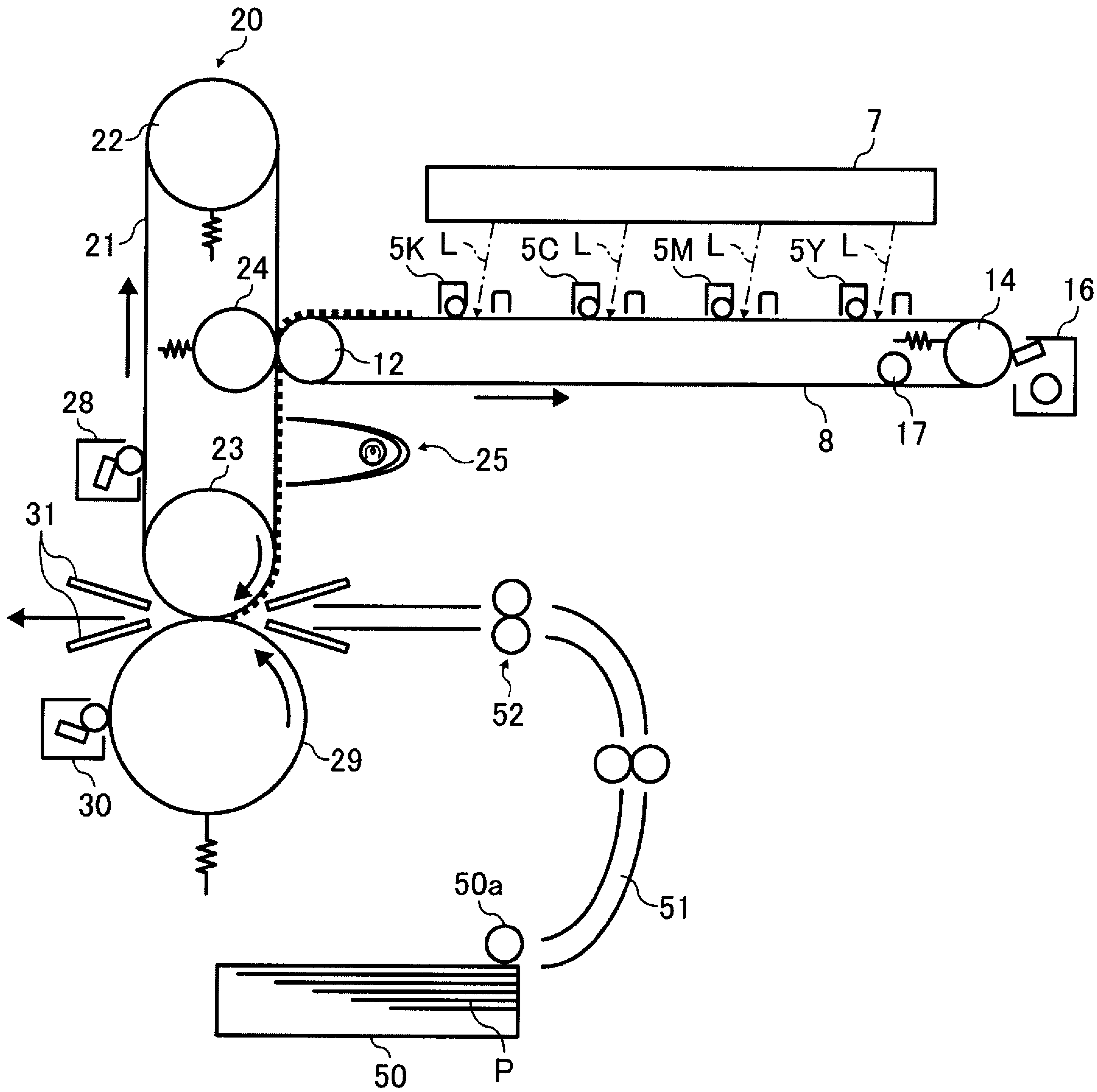
31
52
29
30
50a
51
50
P

FIG. 10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22
21
24
7
5K
L
5C
L
5M
L
5Y
L
14
16
12
28
23
25
8
17
31
52
29
30
50a
51
50
P

IMAGE FORMING APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

This patent application is based on and claims priority under 35 U.S.C. §119 from Japanese Patent Application No. JP2006-253547 filed on Sep. 19, 2006 in the Japan Patent Office, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

Exemplary aspects of the present invention generally relate to an image forming apparatus, and more particularly to an image forming apparatus which transfers and fixes a visible image on a recording medium such as paper.

2. Discussion of the Background

Conventionally, it has been known that an image forming apparatus such as a copier, a facsimile and a printer forms an image on a recording medium, for example, a recording sheet in a following manner.

The visible image, for example, a toner image carried on an image carrier such as a photosensitive drum and an intermediate transfer medium is electrostatically transferred to the recording medium by the effect of the transfer electric field.

Subsequently, the recording sheet is nipped by a fixing nip formed by abutting a heating roller and a pressure roller, for example.

Accordingly, at least one of the abutting members is heated so that the temperature thereof is relatively high. The heat and the nip pressure of the abutting members act on the surface of the recording sheet nipped by the fixing nip. Accordingly, the visible image is fixed thereon.

With an advancement of a high-quality image in recent years, an enhancement of gloss on the visible image on the recording sheet has been desired.

Consequently, the fixing temperature tends to be high so that image forming materials are sufficiently fused, and the gloss of the visible image is enhanced.

In order to realize the fixing process at a high temperature, a fixing power source with a large output capacity is used. Consequently, an increase in an energy consumption and cost is most likely to occur.

Furthermore, the recording sheet is overheated at the fixing nip causing recording sheets to easily stick with one another at a sheet stacking portion.

Conventionally, an image forming apparatus which substantially heats a visible image prior to fixing the visible image on the recording sheet has been proposed.

In the related art image forming apparatus, the transfer-fixing roller abuts against a front surface of the intermediate transfer belt for transferring a toner image or a visible image formed on the photosensitive drum. Accordingly a secondary transfer nip is formed.

Furthermore, a transfer-fixing nip is formed by abutting a pressure roller against the secondary transfer nip. After the toner image primarily transferred from the photosensitive drum to the intermediate transfer belt is secondarily transferred to the surface of the transfer-fixing roller, the toner image is transported to the transfer-fixing nip in conjunction with rotation of the transfer-fixing roller.

At this time, a heater in the transfer-fixing roller or a heater disposed opposite to the transfer-fixing roller or the like substantially heats the toner image. In synchronization with the toner image on the transfer-fixing roller, the toner image is transferred and fixed on the recording sheet nipped by the transfer-fixing nip.

According to this configuration, the toner is heated separately from the recording sheet, and subsequently adhered to the recording sheet.

Thus, it may be able to prevent the recording sheet from being excessively heated and from sticking to a stack of recording sheets at the sheet stacking portion.

Furthermore, when the heater is disposed across from the transfer-fixing roller, it is possible to suppress a heat conduction to the transfer-fixing roller so that an energy consumption is reduced when compared with installation of the heater in the transfer-fixing roller.

However, according to the image forming apparatus configured in the above manner, when the temperature of the surface of the transfer-fixing roller is increased by the heater, and the surface thereof comes into contact with the intermediate transfer belt at the transfer nip described above, the intermediate transfer belt is heated by a small amount. Consequently, it is possible to promote deterioration of the intermediate transfer belt.

Another related art image forming apparatus using a transfer-fixing belt stretchedly arranged between a plurality of rollers instead of the transfer-fixing roller and endlessly travels has been proposed.

A heater disposed across from the transfer-fixing belt heats a toner image on the belt.

According to this configuration, after the belt surface heated by the heater advances to the transfer-fixing nip in order to transfer or fix the toner image on the recording sheet, it is possible to cool down the belt surface while traveling to the transfer nip.

Accordingly, it is possible to suppress deterioration of the intermediate transfer belt due to heat.

However, according to experiments performed by inventors of the present invention, in the image forming apparatus configured in the above-described manner, a disturbance or a hollow portion may easily be generated in the toner image when secondarily transferring the toner image from the intermediate transfer belt to the transfer-fixing belt. This phenomena is hereinafter referred to as a hollow defect.

In the image forming apparatus, the pressure roller in contact with the rear surface of the transfer-fixing belt presses the transfer-fixing belt against intermediate transfer belt so as to form a secondary transfer nip.

Conventionally, it has been known that when the pressure at the transfer nip, for example, a secondary transfer nip (hereinafter referred to as a fixing nip pressure) is excessively high, the hollow defect is most likely be generated in the toner image.

According to the above-described related art image forming apparatus, when the recording sheet is nipped by the transfer-fixing nip separately provided from the secondary transfer nip, a rapid stress is applied to the transfer-fixing belt, and thus a speed of the transfer-fixing belt slows down for a brief moment.

When the recording sheet is ejected from the transfer-fixing nip, the speed of the transfer-fixing belt increases for a brief moment due to the rapid decrease in the stress.

Consequently, when the speed of the transfer-fixing belt fluctuates, a tension of the transfer-fixing belt in the proximity of the secondary transfer nip temporarily fluctuates by a large amount.

As a result, with this configuration in which the transfer-fixing belt is stretchedly arranged in a proximity of the secondary transfer nip in a manner as illustrated in FIG. **1**, for example, the belt tension in directions shown by arrows A or B temporarily fluctuates by a large amount due to the rapid fluctuation of the speed of the transfer-fixing belt **21**.

When the tension in the directions A and B is loosened, the pressure of a pressure roller **24** in a direction shown by an arrow C may increase. Consequently, a nip pressure formed by abutting an intermediate transfer belt **11** serving as an image carrier and the transfer-fixing belt **21** increases.

As a result, the hollow defect is induced in the toner image.

SUMMARY OF THE INVENTION

In view of the foregoing, exemplary embodiments of the present invention provide an image forming apparatus which includes an image carrier, an endless transfer-fixing belt, a pressure member and a heater.

The image carrier bears a visible image on its surface which endlessly travels. The endless transfer-fixing belt is stretchedly disposed between a plurality of spanning members, and contact a front surface thereof to the image carrier so as to form a transfer nip while contacting another member other than the image carrier to form a transfer-fixing nip. The pressure member presses the transfer-fixing belt to the image carrier while contacting a backside of the transfer-fixing belt at the transfer nip. The heater heats the visible image.

The visible image on the image carrier is transferred onto the front surface of the transfer-fixing belt at the transfer nip and is transported to the transfer-fixing nip while heated by the heater, where the visible image is transferred and fixed on a recording member.

The transfer-fixing belt is stretchedly arranged such that the transfer-fixing belt travels in a direction substantially perpendicular to a pressure direction of the pressure member in the proximity of the transfer nip.

In one exemplary embodiment, the pressure member includes a curved surface having a specific curvature and contacting the transfer fixing belt.

In one exemplary embodiment, the following relationship is satisfied:

$$T_1 \sin \theta_1 + T_2 \sin \theta_2 < 2.5 \times S,$$

where θ_1 [degree] is an angle between a first virtual line segment L_1 extending from a winding start point P_1 of the transfer-fixing belt relative to the curved surface of the pressure member to a center of a virtual circle having the same curvature as that of the curved surface, which is drawn along a curved direction of the curved surface, and a third virtual line segment L_3 extending from the center point of the transfer nip in the belt traveling direction to the center of the virtual circle; θ_2 [degree] is an angle between a second line segment L_2 extending from a winding finish point P_2 of the transfer-fixing belt relative to the pressure member to the center of the virtual circle and the third line segment L_3; S [cm^2] is an area of the transfer nip; T_1 [N] is a tension near the winding start point P_1 of the transfer-fixing belt in the resting state; and T_2 [N] is a tension near the winding finish point P_2 of the transfer-fixing belt in the resting state.

In one exemplary embodiment, the winding start point P_1 is disposed upstream in the belt traveling direction further than a transfer nip entrance point where the image carrier and the transfer-fixing belt start contacting each other.

In one exemplary embodiment, the winding finish point P_2 is disposed downstream in the belt traveling direction further than a transfer nip exit point where the image carrier and the transfer-fixing belt start separating from each other after passing the transfer nip.

In one exemplary embodiment, the pressure member is a plate-shaped member curved at a specific curvature.

In one exemplary embodiment, the pressure member is formed of a material having a high stiffness.

Additional features and advantages of the present invention will be more fully apparent from the following detailed description of exemplary embodiments, the accompanying drawings and the associated claims.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the disclosure and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description of exemplary embodiments when considered in connection with the accompanying drawings, wherein:

FIG. **1** is an enlarged view illustrating a related art transfer-fixing belt in the vicinity of a secondary transfer nip;

FIG. **2** is a schematic diagram illustrating an image forming apparatus, for example, a printer, according to exemplary embodiments of the present invention;

FIG. **3** is an enlarged view illustrating one example of a process unit of the image forming apparatus of FIG. **2**;

FIG. **4** is a graphical representation of a relationship between a transfer nip pressure and a level of hollow defect according to exemplary embodiments;

FIG. **5** is an enlarged view illustrating a secondary transfer nip and a surrounding structure thereof in the image forming apparatus according to exemplary embodiments;

FIG. **6** is an enlarged view illustrating the secondary transfer nip and the surrounding structure thereof in the image forming apparatus according to exemplary embodiments;

FIG. **7** is an enlarged view illustrating a minimum distance h from a belt winding start point P_1 to a surface of a secondary transfer-drive roller;

FIG. **8** is a schematic diagram illustrating the secondary transfer nip and the peripheral structure thereof according to exemplary embodiments;

FIG. **9** is a schematic diagram illustrating the image forming apparatus according to another exemplary embodiment; and

FIG. **10** is a schematic diagram illustrating the image forming apparatus according to still another exemplary embodiment.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

It will be understood that if an element or layer is referred to as being "on," "against," "connected to" or "coupled to" another element or layer, then it can be directly on, against connected or coupled to the other element or layer, or intervening elements or layers may be present.

In contrast, if an element is referred to as being "directly on," "directly connected to" or "directly coupled to" another element or layer, then there are no intervening elements or layers present. Like numbers refer to like elements throughout figures. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

Spatially relative terms, such as "beneath," "below," "lower," "above," "upper" and the like, may be used herein for ease of description to describe an element or an element's feature or relationship to another element(s) or feature(s) as illustrated in the figures.

It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures.

For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the term such as "below" can encompass both an orientation of above and below.

The device may be otherwise oriented at various angles (i.e. rotated 90 degrees or at other orientations), and the spatially relative descriptors used herein are interpreted accordingly.

Although the terms first, second, etc. may be used herein to describe various elements, components, regions, layers and/or sections, it should be understood that these elements, components, regions, layers and/or sections should not be limited by these terms.

These terms are used only to distinguish one element, component, region, layer or section from another element, component, region, layer or section. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the present invention.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present invention. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

It will be further understood that the terms "includes" and/or "including", when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

In describing exemplary embodiments illustrated in the drawings, specific terminology is employed for the sake of clarity. However, the disclosure of this patent specification is not intended to be limited to the specific terminology so selected and it is to be understood that each specific element includes all technical equivalents that operate in a similar manner.

Exemplary embodiments of the present invention are now explained below with reference to the accompanying drawings.

In the later described comparative example, exemplary embodiment, and alternative example, for the sake of simplicity of drawings and descriptions, the same reference numerals will be given to constituent elements such as parts and materials having the same functions, and the descriptions thereof will be omitted unless otherwise stated.

Typically, but not necessarily, paper is the medium from which is made a sheet on which an image is to be formed. Other printable media are available in sheets and their use here is included. For simplicity, this Detailed Description section refers to paper, sheets thereof, paper feeder, etc. It should be understood, however, that the sheets, etc., are not limited only to paper.

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, particularly to FIG. **2**, a structure of an image forming apparatus, for example, a printer using an electrophotographic method according to an exemplary embodiment of the present invention is described.

FIG. **2** is a schematic diagram illustrating an image forming apparatus serving as a printer according to an exemplary embodiment of the present invention.

The printer in one embodiment includes at least photosensitive drums **1**Y, **1**M, **1**C and **1**K serving as a drum-type latent image carrier, four process units **6**Y, **6**M, **6**C and **6**K, an optical writing unit **7** serving as a latent image forming mechanism, an intermediate transfer unit **10** and so forth.

The letter symbols Y, M, C and K herein denote colors of yellow, magenta, cyan and black, respectively.

The process units **6**Y, **6**M, **6**C and **6**K carry out an image forming process for forming toner images of different colors: yellow (Y), magenta (M), cyan (C) and black (K). The process units **6**Y, **6**M, **6**C and **6**K may be replaced when the process units **6**Y, **6**M, **6**C and **6**K reach end of life.

The structure of the process units **6**Y, **6**M, **6**C and **6**K are similar, if not the same, except that toners of respective colors as an image forming material are different. Thus, a description will be given of the process unit **6**Y forming an yellow image (e.g., Y-image) as a representative example.

As shown in FIG. **3**, the process unit **6**Y for forming an yellow toner image at least includes the drum-type photosensitive drum **1**Y serving as a latent image carrier, a drum cleaning unit **2**Y, a discharging unit **3**Y, a charging unit **4**Y, a developing unit **5**Y and so forth.

The photosensitive drum **1**Y is a drum-shape metal tube covered with a photosensitive layer and is rotatively driven in a clockwise direction by a drive mechanism (not shown).

The charging unit **4**Y includes a charging roller to which a charging bias is applied by a charging bias power source (not shown) and rotatively driven while coming into contact with or coming closer to the photosensitive drum **1**Y. Accordingly, the surface of the photosensitive drum **1**Y is evenly charged by the electric discharge of the charging roller.

Alternatively, instead of using the charging roller, a charging brush may be utilized to charge the photosensitive drum **1**Y. The photosensitive drum **1**Y may be evenly charged by means of corona charging.

The surface of the photosensitive drum **1**Y is evenly charged. Subsequently, the surface thereof is exposed and scanned by a laser beam L emitted from the optical writing unit **7**. Accordingly, the photosensitive drum **1**Y carries an electrostatic latent image of yellow.

The electrostatic latent image of yellow is developed by the developing unit **5**Y using a yellow toner so that a yellow toner image is formed. Subsequently, the yellow toner image is primarily transferred to the intermediate transfer belt **11**.

The drum cleaning unit **2**Y removes toner remained on the photosensitive drum **1**Y after the primary transfer process.

The discharging unit **3**Y removes a residual charge from the photosensitive drum **1**Y after cleaning. Accordingly, the surface of the photosensitive drum **1**Y is initialized and prepared for a subsequent image forming operation.

Similar to the process unit **6**Y, in the process units **6**M, **6**C and **6**K of other colors, toner images of magenta, cyan and black are formed on the photosensitive drums **1**M, **1**C and **1**K, respectively.

As shown in FIG. **2**, the optical writing unit **7** is disposed above the process units **6**Y, **6**M, **6**C and **6**K.

The optical writing unit **7** serving as a latent image forming mechanism optically scans the photosensitive drums **1**Y through **1**K of respective process units **6**Y through **6**K with a laser beam L based on an image information transmitted from a personal computer (not shown), for example.

According to the optical scanning, electrostatic latent images of yellow, magenta, cyan and black are formed on the photosensitive drums **1**Y, **1**M, **1**C and **1**K, respectively.

The optical writing unit **7** irradiates the photosensitive drums **1**Y through **1**K with the laser beam L emitted from a light source by way of a plurality of optical lenses and mirrors while a polygon mirror which is rotatively driven by a motor (not shown) scans the laser beam L in a main scanning direction.

Instead of the optical writing unit **7** of the exemplary embodiment, a structure using an LED array which emits an LED light may be used.

As shown in FIG. **2**, a sheet feed cassette **50** is provided below the intermediate transfer belt **11**. The sheet feed cassette **50** stores a sheet bundle consisting of a plurality of recording sheets P serving as a recording medium.

A sheet feed roller **50***a* is pressed against the top sheet of the recording sheet P.

When the sheet feed roller **50***a* is rotatively driven, the top sheet of the recording sheets P is sent to a sheet feed path **51**.

Subsequently, the recording sheet P is transported to a space between the registration rollers **52** disposed at the end of the sheet feed path **51**.

A pair of registration rollers **52** is each rotatively driven so as to nip the recording sheet P. As soon as the registration rollers **52** nip the recording sheet P, the rotation thereof is temporarily stopped.

As will be later described, the rotation is resumed in synchronization with a transfer timing of a toner image onto the recording sheet P at a transfer-fixing nip.

As shown in FIG. **2**, beneath the process units **6**Y, **6**M, **6**C and **6**K, the intermediate transfer unit **10** is disposed. In the intermediate transfer unit **10**, the intermediate transfer belt **11** serving as an intermediate transfer member and an image carrier is stretchedly arranged and endlessly moved.

In addition to the intermediate transfer belt **11**, the intermediate transfer unit **10** further includes a belt cleaning unit **16**, a belt cooling unit **17**, four primary transfer bias rollers **12**Y, **12**M, **12**C and **12**K, a secondary transfer-drive roller **13** serving also as a drive roller, a tension roller **14** and so forth.

The rear surface or an inner surface of the intermediate transfer belt **11** is supported and stretchedly arranged at a predetermined tension by spanning rollers.

The intermediate transfer belt **11** is endlessly moved by the secondary transfer-drive roller **13** rotatively driven in a counterclockwise direction shown in FIG. **2** by a drive mechanism (not shown).

The intermediate transfer belt **11** endlessly moving is nipped by the four primary transfer bias rollers **12**Y, **12**M, **12**C and **12**K, and the photosensitive drums **1**Y, **1**M, **1**C and **1**K. Accordingly, a primary transfer nip is formed at places where the photosensitive drums **1**Y, **1**M, **1**C and **1**K abut the surface of the intermediate transfer belt **11**.

The primary transfer bias rollers **12**Y, **12**M, **12**C and **12**K apply a transfer bias of reverse polarity (i.e., positive polarity) relative to a charging polarity of toner. However, the primary transfer bias rollers **12**Y, **12**M, **12**C and **12**K may be of a charger-type allowing a discharge from an electrode.

When the intermediate transfer belt **11** endlessly travels passing the primary transfer nips of each color, the toner images of yellow, magenta, cyan and black on the photosensitive drums **1**Y, **1**M, **1**C and **1**K are primarily transferred and sequentially overlapped one on another on the intermediate transfer belt **11**.

Accordingly, the toner images of four colors are overlapped one on another forming a four-color toner image on the intermediate transfer belt **11**.

As shown in FIG. **2**, toward the left of the intermediate transfer unit **10**, a transfer-fixing unit **20** which causes a transfer-fixing belt **21** to endlessly move is provided.

The transfer-fixing belt **21** comes into contact with the intermediate transfer belt **11** at a position where the intermediate transfer belt **11** is laid on the secondary transfer-drive roller **13**. Accordingly, a secondary transfer nip is formed therebetween.

After passing the secondary transfer nip, an inner loop of the intermediate transfer belt **11** comes into contact with the belt cooling unit **17** at a position before the intermediate transfer belt **11** advances to the primary transfer nip of yellow to which the primary transfer process is performed first among yellow, magenta, cyan and black.

The belt cooling unit **17** is equipped with a cooling member, for example, a heat pipe formed of a material having a high heat conductivity.

When the belt cooling unit **17** causes the cooling member contacting the rear surface of the intermediate transfer belt **11** to rotate, the intermediate transfer belt **11** is cooled from the rear surface thereof.

Cooling of the intermediate transfer belt may be enhanced when a fan (not shown) or the like blows air to the cooling member which in turn cools the belt.

A secondary transfer bias supply mechanism (not shown) applies to the secondary transfer-drive roller **13** of the intermediate transfer unit **10** the secondary transfer bias having the same polarity as the charging polarity of the toner (i.e., a direct-current bias of −0.5 to −2 kV or a superimposed direct-current bias on an alternating current).

As will be later described, a pressure roller **24** of the transfer-fixing unit **20** is connected to ground. Accordingly, a secondary transfer electric field to electrostatically transport toner from the intermediate transfer belt **11** to the transfer-fixing belt **21** is formed in the secondary transfer nip formed between the secondary transfer-drive roller **13** and the pressure roller **24**.

The four-color toner image advances to the secondary transfer nip in conjunction with traveling of the intermediate transfer belt **11**.

Subsequently, the secondary transfer electric field and the nip pressure act on the four-color toner image so that the four-color toner image is secondarily transferred on the front surface of the transfer-fixing belt **21** at once.

The transfer-fixing unit **20** at least includes a tension roller **22**, a transfer-fixing/drive roller **23** and the pressure roller **24**. The endless transfer-fixing belt **21** is stretchedly arranged between these rollers causing the endless transfer-fixing belt **21** to endlessly travel in a clockwise direction.

The transfer-fixing unit **20** further includes a heating unit **25**, a belt cleaning unit **28**, a fixing pressure roller **29** and so forth.

The transfer-fixing belt **21** may include an endless-belt base formed of metal (i.e., iron), a heat resistant resin (i.e., polyimide), or any other suitable material.

On the surface the belt base, an elastic layer formed of an elastic material (i.e., silicone rubber) and a release enhancement layer formed of a material having a low friction coefficient (i.e., a fluoro-rubber) are subsequentially laminated.

The belt base preferably has a thickness of less than or equal to 0.1 mm in order to shorten a warm-up time in which a heat source reaches a predetermined temperature and enhancement of an endless mobility.

The elastic layer preferably has a thickness of no more than 0.1 mm in order to demonstrate a universal hardness of the surface layer. Furthermore, when taking the warm-up time into account, the thickness of no more than 0.5 mm is preferred.

The release enhancement layer preferably has a thickness of no more than 30 μm in order to demonstrate the universal hardness of the surface layer.

The transfer-fixing/drive roller **23** at least includes a non-hollow roller core formed of a metal, for example, iron. The non-hollow roller core is covered with an elastic layer made of an elastic material, for example, a rubber, having a thickness of approximately 1 to 3 mm.

The transfer-fixing/drive roller **23** is rotatively driven in a clockwise direction by a drive mechanism (not shown). Accordingly, the transfer-fixing belt **21** is endlessly moved in a clockwise direction.

A later-described fixing pressure roller **29** exerts a relatively heavy weight on the transfer-fixing/drive roller **23**. Therefore, a material having a surface hardness of no less than 80 on the Asker C scale is preferable for the transfer-fixing/drive roller **23**.

In order to shorten the warm-up time by enhancing the thermal insulation performance relative to the transfer-fixing belt **21**, a rigid heat-insulating layer formed of a porous ceramic or the like may be provided between a roller core and the elastic layer.

The tension roller **22** provides a tension to the transfer-fixing belt **21** when a tension spring biases the tension roller **22**.

A pressure spring biases the pressure roller **24** serving as a pressure member against the intermediate transfer unit **10** so that the transfer-fixing belt **21** is pressed against the intermediate transfer belt **11** at a place where the intermediate transfer belt **11** is laid on the secondary transfer-drive roller **13**.

Consequently, the front surface of the transfer-fixing belt **21** is pressed against the front surface of the intermediate transfer belt **11** so that the secondary transfer nip is formed therebetween.

The pressure roller **24** at least includes a roller core formed of a metal, for example, iron. On the surface of the metal (i.e., iron) roller core, a heat insulating layer made of, for example, a porous ceramic having a high hardness, an elastic layer made of an elastic material such as a silicone rubber, and a release enhancement layer made of a fluoro-rubber or the like are sequentially laminated.

A pressure spring biases the fixing-pressure roller **29** against the transfer-fixing belt **21** at a position where the transfer-fixing belt **21** is laid on the transfer-fixing/drive roller **23**.

Accordingly, the transfer-fixing belt **21** and fixing-pressure roller **29** come into contact with each other so that the transfer-fixing nip is formed therebetween.

The four-color toner image is secondarily transferred from the intermediate transfer belt **11** to the transfer-fixing belt **21** at the secondary fixing nip. Subsequently, the secondarily transferred four-color toner image is transported to the transfer-fixing nip in conjunction with the endless movement of the transfer-fixing belt **21**.

At this time, the four-color toner image passes the side of the belt heating unit **25** facing the front surface of the transfer-fixing belt **21** through a given gap.

The belt heating unit **25** at least includes a heater **26** and a reflective plate **27** which reflects a thermal light from the heater **26** onto the transfer-fixing belt **21**. The heater **26** may be a halogen heater, for example.

The radiant energy emitted from the heater **26** may directly be applied to the transfer-fixing belt **21**. The radiant energy emitted from the heater **26** may be reflected on the reflective plate **27** so that the radiant energy is concentrated on the belt. Accordingly, the four-color toner image on the belt is adequately heated.

A thermistor (not shown) detects a surface temperature of the transfer-fixing belt **21**. Based on the detection result, the "on/off" of the power source of the heater **26** may be controlled. Accordingly, the surface temperature of the transfer-fixing belt **21** is prevented from rising beyond a predetermined temperature.

The four-color toner image adequately heated by the heating unit **25** serving as a heating mechanism advances to the transfer-fixing nip in conjunction with the endless movement of the transfer-fixing belt **21**.

When the four-color toner image comes into contact with the recording sheet P sent from a pair of the above-described registration rollers **52** in the transfer-fixing nip, the four-color toner image is thirdly transferred onto the recording sheet P by the effect of self viscosity and the nip pressure.

In the printer according to the exemplary embodiment, the four-color toner image is pressed on the transfer-fixing belt **21** separately from the recording sheet P prior to fixing the four-color toner image on the recording sheet P.

Accordingly, a heat loss is reduced when compared with a configuration in which the recording sheet P and the four-color toner image are pressed together while the four-color image is fixed on the recording sheet P.

According to experiments performed by the present inventors, this configuration achieved an adequate gloss and a fixability when the temperature of the transfer belt **21** was increased to a relatively low temperature of 110 to 120 deg. C.

When a conductive fluoro-resin material in which a conductive material, for example, carbon, is dispersed is used for the release enhancement layer, the elastic layer and the roller core of the transfer-fixing belt **21**, a secondary transfer electric field is formed between the release enhancement layer of the intermediate transfer belt **11** and the release enhancement layer of the transfer-fixing belt **21**.

Accordingly, the secondary transfer bias is further reduced to a low voltage. Furthermore, toner scattering at the secondary transfer may be reduced.

A small amount of toner which has not been secondarily transferred to the transfer-fixing belt **21** is adhered to the surface of the intermediate transfer belt **11** after passing the secondary transfer nip.

The belt cleaning unit **16** abutting the front surface of the intermediate transfer belt **11** at a position where the intermediate transfer belt **11** is laid on the tension roller **14** removes the toner residue from the intermediate transfer belt **11**.

A small amount of toner which has not been thirdly transferred to the recording sheet P is adhered on the surface of the transfer-fixing belt **21** after passing the transfer fixing nip.

The belt cleaning unit **28** abutting the transfer-fixing belt **21** at a spanned position between the tension roller **22** and the transfer-fixing/driving roller **23** removes the toner residue from the surface of the transfer-fixing belt **21**.

Paper dust traveled from the recording sheet P may be adhered on the surface of the fixing-pressure roller **29** after passing the transfer-fixing nip.

The roller cleaning unit **30** abutting the fixing-pressure roller **29** removes the paper dust from the surface of the fixing-pressure roller **29**.

The recording sheet P ejected from the transfer-fixing nip is guided by guide plates **31** and is ejected out of the printer.

In the above-described secondary transfer nip, the transferability of the four-color toner image depends largely on a contact pressure between the intermediate transfer belt **11** and the transfer-fixing belt **21**.

The contact pressure in the transfer nip is hereinafter referred to as transfer nip pressure.

Referring now to FIG. **4**, there is provided a graphical representation of a relationship between a transfer nip pressure and a level of hollow defect in a four-color toner image according to the experiments performed by the present inventors.

In FIG. **4**, Level **5** of the hollow defect indicates that no hollow defect was detected in a test image when the test image was printed out and examined by a magnifier with the magnification power of 25×.

Level **4** of the hollow defect indicates that no hollow defect was detected in the test image when visually examined with the naked eye while a slight hollow defect was detected when the test image was examined by a magnifier with the magnification power of 25×.

Level **3** of the hollow defect indicates that a hollow defect was detected when the test image was closely examined with the naked eye.

Level **2** of the hollow defect indicates that a hollow defect was detected when the test image was examined with the naked eye.

Level **1** of the hollow defect indicates that a hollow defect was easily detected when the test image was examined with the naked eye, and image degradation was significant.

Acceptable levels of the hollow defect are levels **3** through **5**. The levels **1** and **2** are considered as "not acceptable."

Conditions for Experiments:

The following conditions were used for the experiments.

The base material for the intermediate transfer belt **11**: Polyimide resin

Thickness of the belt: 80 μm

The transfer-fixing belt **21** includes a polyimide base on which an elastic layer of silicone rubber (Si-rubber) having a thickness of 300 μm and a release enhancement layer of PTFE (polytetrafluoroethylene) having a thickness of 10 μm are laminated.

Toner: Pulverized toner

As shown in FIG. **4**, when the transfer nip pressure increased, a hollow defect was likely to be generated. In order to achieve an acceptable level of the hollow defect, that is, Level **3** and above, the transfer nip pressure needed to be no more than 10 N/cm^2.

Furthermore, when the transfer nip pressure was reduced to 5 N/cm^2 or less, the level in which no hollow defect was detected with the naked eye was achieved. In other words, Level **4** of the hollow defect and above was achieved.

The transfer nip pressure is preferably set to no more than 5 N/cm^2 at the secondary transfer nip.

However, when the tension of the transfer-fixing belt **21** serving as a drag force relative to the pressure spring which biases the pressure roller **24** is loosened for some reason, the spring bias of the pressure spring relative to the pressure roller **24** is enhanced.

Consequently, the transfer nip pressure increases at the secondary transfer-fixing nip.

When the front end of the recording sheet P is nipped by the transfer-fixing nip, a stress relative to the transfer-fixing/drive roller **23** temporarily, but suddenly increases. Consequently, the speed of the transfer-fixing belt **21** drops for a second.

In such a situation where the speed fluctuates, when the transfer-fixing belt **21** is stretchedly arranged in a manner as shown in FIG. **1**, the tension of the transfer-fixing belt **21** stretchedly arranged between the tension roller **22** and the pressure roller **24** temporarily increases while the tension of the transfer-fixing belt **21** between the pressure roller **24** and the transfer-fixing drive roller **23** temporarily decreases.

When the resultant force of the tensions is further reduced, the spring bias of the pressure spring relative to the pressure roller **24** is enhanced, causing the secondary transfer nip pressure to increase.

Furthermore, when the rear end of the recording sheet P is ejected from the transfer-fixing nip, the stress relative to the transfer-fixing/drive roller **23** temporarily drops, and the speed of the transfer-fixing belt **21** suddenly increases.

In such a situation where the speed fluctuates, when the transfer-fixing belt **21** is stretchedly arranged in a manner as shown in FIG. **1**, the tension of the transfer-fixing belt **21** stretchedly arranged between the tension roller **22** and the pressure roller **24** temporarily decreases while the tension of the transfer-fixing belt **21** stretchedly arranged between the pressure roller **24** and the transfer-fixing/drive roller **23** temporarily increases.

When the resultant force of the tensions is further reduced, the spring bias of the pressure spring relative to the pressure roller **24** is enhanced, causing the secondary transfer nip pressure to increase.

According to the experiments performed by the present inventors, when a relatively thick paper having a thickness of, for example, 100 g/m^2 or more, was used as a recording sheet P, there was a case where the fluctuation of a tension T_1 and a tension T_2 was 100% at a maximum which was twice the tension.

As shown in FIG. **5**, in the printer according to one exemplary embodiment, the transfer-fixing belt **21** is stretchedly arranged such that the transfer belt **21** travels, in the proximity of the secondary transfer nip, in directions (shown by arrows D and E) substantially perpendicular to a pressure direction shown by an arrow C of the pressure roller **24**.

According to this configuration, even if the tension of the transfer-fixing belt **21** fluctuates in the proximity of the secondary transfer nip, the fluctuation of the tension acts on the directions D and E which are the spanning direction of the transfer-fixing belt **21** in the proximity of the secondary transfer nip.

Therefore, the fluctuation of the tension hardly acts on the force in the pressure direction (arrow C direction) relative to the pressure roller **24**.

In other words, even if the tension of the transfer-fixing belt **21** fluctuates, the secondary transfer nip pressure hardly fluctuates.

Therefore, generation of a hollow defect in an image caused by the fluctuation of the transfer-fixing belt **21** is suppressed.

A description will be provided of a printer according to one exemplary embodiment. Unless otherwise specified, the configuration of the printer according to the exemplary embodiment is similar to, if not the same as the printer of the above-described exemplary embodiment.

The belt spanned portion linked to the secondary transfer nip further upstream of the secondary transfer nip and the belt spanned portion linked to the secondary transfer nip downstream of the secondary transfer nip are each moved in the direction perpendicular to the pressure direction (arrow C direction) of the pressure roller **24**.

Accordingly, the fluctuation of the tension of the transfer-fixing belt **21** does not act on the pressure direction. Therefore, the fluctuation of the secondary transfer nip pressure due to the fluctuation of the tension of the transfer-fixing belt **21** is reduced, if not prevented.

However, Level **3** of the hollow defect or above may be achieved when the amount of fluctuation of the tension of the transfer-fixing belt acting on the pressure direction is insignificant.

Referring now to FIG. **6**, there is provided an enlarged view illustrating the secondary transfer nip and a surrounding structure thereof in the printer according to one exemplary embodiment.

In FIG. **6**, a dot Pc refers to a center point of the secondary transfer nip N where the transfer-fixing belt **21** and the intermediate transfer belt **11** come into contact with each other in the belt traveling direction.

A dot P_1 refers to a start point of belt winding of the transfer-fixing belt **21** which endlessly travels relative to the curved surface of the pressure roller **24**.

A dash-dotted line L_1 refers to a first virtual line segment extending from the winding start point P_1 to a center point Pa of a virtual circle having the same curvature as the curvature of the pressure roller **24**.

In the exemplary embodiment, the virtual circle corresponds to a peripheral surface of the pressure roller **24**.

θ_1 refers to an angle between the first virtual line segment L_1 and a third virtual line segment L_3 extending from the center point Pc of the secondary transfer nip to the center Pa of the virtual circle.

A dot P_2 refers to a finish point of a belt winding of the transfer-fixing belt **21** relative to the pressure roller **24**.

θ_2 refers to an angle between a second virtual line segment L_2 extending from the winding finish point P_2 to the center Pa of the virtual circle, and the third virtual line segment L_3.

T_1 refers to a tension in the proximity of the winding start point P_1 of the transfer-fixing belt **21** in the resting state.

T_2 refers to a tension in the proximity of the winding finish point P_2 of the transfer-fixing belt **21** in the resting state.

F_0 refers to a pressure force of the pressure spring which biases the pressure roller **24**.

In FIG. **6**, when S [cm_2] is an area of the secondary transfer nip, the secondary nip pressure per unit area [N/cm_2] is defined as follows:

$$\text{Secondary transfer nip pressure}=(F-(T_1 \sin \theta_1+T_2 \sin \theta_2))/S \quad (1).$$

At the secondary transfer, it is necessary that the secondary transfer-drive roller **13** not be separated from the intermediate transfer belt **11**. Therefore, Equation 1 is modified as follows:

$$0<(F-(T_1 \sin \theta_1+T_2 \sin \theta_2))/S \quad (2).$$

In order to secure the hollow defect within an acceptable level, that is, Level **3** or above, the following relationship is satisfied:

$$0<(F-(T_1 \sin \theta_1+T_2 \sin \theta_2))/S \leqq 10\ \text{N/cm}^2 \quad (3).$$

Furthermore, in order to suppress the hollow defect to the level at which the hollow defect cannot visually be detected with the naked eye, the following relationship is satisfied:

$$0<(F-(T_1 \sin \theta_1+T_2 \sin \theta_2))/S \leqq 5\ \text{N/cm}^2 \quad (4).$$

When the recording sheet P advances to the transfer-fixing nip or the recording sheet P is ejected from the transfer-fixing nip causing the tension of the transfer-fixing belt **21** to fluctuate, it is necessary to satisfy the equations 3 and 4.

In order to satisfy the equations 3 and 4, both angles θ_1 and θ_2 are set to 0 degree so that the transfer-fixing belt **21** travels in a direction perpendicular to the pressure direction of the pressure spring in the proximity of the secondary transfer nip.

Furthermore, even if when the tension is set relatively low, the acceptable level of hollow defect is still achieved even if the angles θ_1 and θ_2 are not 0 degrees, and the fluctuation of the tension causes the pressure force to fluctuate.

Referring back to FIG. **4**, according to the experiments, even if the tension fluctuated, Equation 3 was continued to be satisfied when the secondary transfer nip pressure at the resting state was set at 7.5 N/cm^2, which approximately corresponds to Level **2.5** of the hollow defect, instead of setting it at 10 N/cm^2, which is closed to Level **3** of the hollow defect.

The angles θ_1 and θ_2 were set to a relatively small angle so that the fluctuation of the secondary transfer nip pressure due to the tension fluctuation was no more than 2.5 N/cm^2.

Accordingly, even if the tension fluctuated, the secondary transfer nip pressure was secured at 10 N/cm^2 or less.

A part of the tension of the transfer-fixing belt **21** acts as a drag force against the pressure force of the pressure spring which biases the pressure roller **24** into the intermediate transfer belt **11**.

The drag force is a resultant force of the drag force F_1 and the drag force F_2 as shown in FIG. **6**. The drag force F_1 arises from the tension T_1 further upstream of the secondary transfer nip of the transfer-fixing belt **21**. The drag force F_2 arises from the tension T_2 further downstream of the secondary transfer nip.

Even if the resultant force of the tension T_1 and tension T_2 of the transfer-fixing belt **21** is reduced due to the fluctuation of the belt speed, the level of the hollow defect is secured within the acceptable level, that is, Level **3** when the resultant force of the drag force F_1 and F_2 is no less than 2.5 N/cm^2.

When S [cm_2] is an area of the secondary transfer nip, the drag force F_1 is represented as follows:

$$\text{Drag force } F_1[\text{N/cm}_2]=T_1 \sin \theta_1/S \quad (5).$$

The drag force F_2 is represented as below.

$$\text{Drag force } F_2[\text{N/cm}_2]=T_1 \sin \theta_1/S \quad (6).$$

Therefore, when the angles θ_1 and θ_2 are configured to satisfy the following relationship, the level of the hollow defect is secured within the acceptable level, that is, Level **3**.

$$T_1 \sin \theta_1+T_2 \sin \theta_2<2.5\times S \quad (7).$$

Therefore, in the printer according to the exemplary embodiment, the angles θ_1 and θ_2 are configured to satisfy the equation (7).

When the tension of the transfer-fixing belt **21** is significantly weak, the performance of the transfer-fixing belt **21** may become unstable or the driving force may not be accurately transmitted.

On the contrary, when the tension of the transfer-fixing belt **21** is significantly strenuous, the transfer-fixing belt **21** may be stretched, and/or may be strenuously laid around the roller so that a plastic deformation may occur.

For this reason, the tension is normally configured to be approximately 10 to 50 N.

The width of the secondary transfer nip is normally configured to be in a range between 1 and 10 mm.

However, in such a printer simultaneously performing transfer and fixing processing, it is advantageous to configure the nip width to be relatively narrow so that it becomes possible to suppress the amount of the heat conduction from the transfer-fixing belt **21** to the recording sheet P.

In general, the length of the secondary transfer nip in the direction perpendicular to the belt traveling direction is configured to be approximately 300 to 350 mm in the structure in which the maximum vertical length of a passing sheet corresponds to A3 size paper sheet.

Furthermore, in general, the length of the secondary transfer nip in the direction perpendicular to the belt traveling direction is configured to be approximately 220 to 250 mm in the structure in which the maximum vertical length of a passing sheet corresponds to A4 size paper sheet.

In a first experiment, the present inventors used a printer having a structure similar to, if not the same as the printer shown in FIG. **2**.

The printer used in the experiment is herein after referred to as a test printer. The transfer-fixing belt **21** in the resting state was stretchedly arranged at a tension of 30N.

As described above, when the recording sheet P advances to the transfer-fixing nip, and/or the recording sheet P is ejected from the transfer-fixing nip, the tension may fluctuate twice as much the tension in the resting state.

In other words, it is possible that the tension may fluctuate by ±30N relative to the tension of 30N in the resting state.

In the experiment, the nip width which was a length in the belt traveling direction in the secondary transfer nip of the test printer was set to 0.1 cm.

The nip length in the direction perpendicular to the belt traveling direction was set to 32 cm which may accommodate A3 size paper.

Therefore, the area S of the secondary transfer nip was: $0.1\times32=3.2\ cm^2$.

The secondary transfer nip pressure was set to 7.5 N/cm^2.

According to the test printer having the above-described structure, in order to maintain the level of the hollow defect within the acceptable level, that is, Level **3** the following relationship is satisfied:

$$30 \sin \theta_1+30 \sin \theta_2<2.5\times3.2\ cm^2 \quad (8).$$

When the above equation is expanded, the following equation is obtained.

$$\theta_1+\theta_2<15.4 \text{ degrees} \quad (9).$$

An experiment was performed when the sum of the angle θ_1 and the angle θ_2 in the test printer was configured to be no more than 15.4 degrees, and a test image was continuously printed.

According to the experiment, even after more than 1000 prints were made, the level of the hollow defect was Level **3** or above in all the prints.

In a second experiment, an experiment was performed when the transfer-fixing belt **21** was stretchedly arranged at a tension of 50 N in the resting state.

As described above, when the recording sheet P advances to the transfer-fixing nip, and/or the recording sheet P is ejected from the transfer-fixing nip, the tension may fluctuate twice as much the tension in the resting state.

In other words, it is possible that the tension may fluctuate by ±50 N relative to the tension of 50N in the resting state.

In the second experiment, the nip pressure, the nip width and the nip area of the secondary transfer nip were the same as that of the experiment 1.

According to the test printer having the above-described structure, in order to maintain the level of the hollow defect within the acceptable level, that is, Level **3**, the following relationship is satisfied:

$$50 \sin \theta_1+50 \sin \theta_2<2.5\times3.2\ cm^2 \quad (10).$$

When the above equation is expanded, the following equation is obtained.

$$\theta_1+\theta_2<6.6 \text{ degrees} \quad (11).$$

An experiment was performed when the sum of the angle θ_1 and the angle θ_2 in the test printer was configured to be no more than 6.6 degrees, and a test image was continuously printed.

According to the experiment, even after more than 1000 prints were made, the level of the hollow defect was Level **3** or above in all the prints.

As described above, when both angles θ_1 and θ_2 are set to 0 degrees, it is possible to reduce, if not prevent, the hollow defect caused by the fluctuation of the tension of the transfer-fixing belt **21**.

In a third experiment, the sum of the angles θ_1 and θ_2 was set to 0 degrees in the test printer. The following conditions were used for the experiments.

Conditions for Experiments:

Diameter of the pressure roller **24**: 40 mm

Diameter of the secondary transfer-drive roller **13**: 30 mm

Thickness of the transfer-fixing belt **21**: 0.4 mm

Angle θ_1: 2.5 degrees

Angle θ_2: 2.5 degrees

Secondary transfer nip angle: 7 degrees

The secondary transfer nip angle is an angle between a line segment extending from the center of the roller **13** to a nip entrance point and a line segment extending from the center of the roller **13** to a nip exit point.

Tension (T_1 and T_2): 30 N

Pressure force by the pressure spring F_0: 40 N

Secondary transfer nip pressure in the resting state: 4.2 N/cm^2

When a continuous printing was performed in the condition described above, no hollow defect which can be visually detected with the naked eye was generated.

However, there were some irregularities in the test image. The cause was known that when the angles θ_1 and θ_2 were substantially small, the transfer-fixing belt **21** and the intermediate transfer belt **11** were forced to come into contact with each other in the vicinity of the secondary fixing nip due to slight waving or wrinkles of the belts.

Thus, it is desirable that the winding start point P_1 is positioned further upstream in the belt traveling direction than the entrance point of the secondary transfer nip.

Thereby, it is possible to reduce, if not prevent, belt waving or wrinkles in the vicinity of the nip entrance when the transfer-fixing belt **21** is laid on the pressure roller **24** in the vicinity of the secondary transfer nip and upstream of the secondary transfer nip before the transfer-fixing belt **21** advances to the secondary transfer nip.

Furthermore, it is desirable that the winding finish point P_2 is positioned further downstream in the belt traveling direction than the exit point of the secondary transfer nip.

Thereby, it is possible to reduce, if not prevent, belt waving or wrinkles in the vicinity of the nip exit when the transfer-fixing belt is laid on the pressure roller **24** by a predetermined amount after passing the secondary transfer nip.

Referring now to FIG. **7**, there is provided an enlarged view for explaining a minimum distance h from the winding start point P_1 of the transfer-fixing belt **21** relative to the pressure roller **24** to the surface of the secondary transfer-drive roller **13**.

In FIG. **7**, R represents a radius of the pressure roller **24**. r represents a radius of the secondary transfer-drive roller **13**. α represents an angle between a virtual line segment extending from the center of the secondary transfer nip Pc to the center of the secondary transfer-drive roller **13** and a virtual line segment extending from the center of the secondary transfer-drive roller **13** to the winding start point P_1.

As described above, it is desirable that the winding start point P_1 is positioned further upstream in the belt traveling direction of the transfer-fixing belt **21** than the secondary transfer nip entrance.

Furthermore, it is desirable that the winding finish point P_2 is positioned further downstream in the belt traveling direction of the transfer-fixing belt **21** than the secondary transfer nip exit.

However, even if the winding start point P_1 is positioned upstream of the nip entrance point, when the minimum distance between the winding start point P_1 and the secondary transfer-drive roller **13** is significantly short, irregularities in the image may not be effectively prevented.

In addition, even if the winding finish point P_2 is positioned further downstream than the nip entrance point, when the minimum distance between the winding finish point P_2 and the secondary transfer-drive roller **13** is significantly short, irregularities in the image may not be effectively prevented.

In light of the above, the present inventors performed an experiment in which the minimum distance h between the winding start point P_1 and the secondary transfer-drive roller **13** was varied, and test images were printed out to examine image irregularities in the test printer.

The transfer-fixing belt **21** used in the experiment included a base made of polyimide resin having a thickness between 50 to 150 μm on which an elastic layer of rubber having a thickness of 100 to 500 μm, and a release enhancement layer of PTFE (polytetrafluoroethylene) having a thickness of 3 to 15 μm were laminated.

The minimum distance between the winding finish point P_2 and the secondary transfer-drive roller **13** was set to the same value as the above-described minimum distance h.

The result of this experiment is shown in Table 1.

TABLE 1

MINIMUM DISTANCE h (mm)	IMAGE IRREGULARITY
0	YES
0.5	YES
1	NO
1.5	NO
2	NO
2.5	NO

As shown in TABLE 1, when both the minimum distances between the winding start point P_1 and the secondary transfer-drive roller **13**, and the minimum distance between the winding finish point P_2 and the secondary transfer-drive roller **13** were set to be 0.5 mm or less, image irregularities occurred.

On the contrary, when both the minimum distances between the winding start point P_1 and the secondary transfer-drive roller **13**, and the minimum distance between the winding finish point P_2 and the secondary transfer-drive roller **13** were set to be more than or equal to 1 mm, image irregularities were prevented.

However, the relationship between the appropriate minimum distance, and the angles θ_1 and θ_2 varies depending on the curvature of the pressure roller **24** and the secondary transfer-drive roller **13**.

As a reference, the relationship between the appropriate minimum distance h, and the angles θ_1 and θ_2 is represented by the following equations. When indicating either θ_1 or θ_2, a symbol θ is used.

$$R \sin \theta=(r+h)\sin \alpha \quad (12)$$

$$R \cos \theta+(r+h)\cos \theta=R+r \quad (13)$$

When Equations 12 and 13 are modified, the following equations are obtained.

$$\sin \alpha=R \sin \theta/(r+h) \quad (14)$$

$$\cos \alpha=(R+r-R \cos \theta)/(r+h) \quad (15)$$

The following equation can be obtained according to an equation $\sin^2 \alpha+\cos^2 \alpha=1$.

$$((R \sin \theta)/(r+h))^2+((R+r-R \cos \theta)/(r+h))^2=1 \quad (16)$$

When $\cos \theta=\sqrt{}(1-\sin^2 \theta)$ is substituted, the following equation is obtained.

$$((R \sin \theta)/(r+h))^2+((R+r-R\sqrt{}(1-\sin^2 \theta)/(r+h))^2=19 \quad (17)$$

When Equation 17 is organized in terms of sin θ, the following equation is obtained.

$$\sin \theta=\sqrt{}(4R^2(R+r)^2-((R^2+(R+r)^2-(r+h)^2))^2/2R(R+r) \quad (18)$$

The printer according to the exemplary embodiment uses the pressure roller **24** having a high stiffness. The stiffness herein refers to a stiffness which can resist against wrinkles generated in the transfer-fixing belt **21**.

The pressure roller **24** using a material such as metal, hard resin, ceramic, and hard rubber may be considered as having a high stiffness.

A conductive material may be dispersed on the surface of the above materials or within the materials so that these materials may serve as an electrode which performs electrostatic transfer when needed.

When using a pressure member which does not perform the surface movement, but causes the transfer-fixing belt **21** to slidably move, instead of the pressure roller **24**, the surface of the pressure member has mirror finishing, or the surface is coated with a fluoroethylene resin or a lubricant such as a silicone oil in order to enhance slippage relative to the transfer-fixing belt **21**.

When the pressure member has a relatively large heat capacity, it may take time to heat the transfer-fixing belt **21**. Therefore, it is not preferable.

In addition, when the coefficient of thermal expansion of the pressure member is relatively large, it is difficult to maintain a certain accuracy of the secondary transfer nip.

Therefore, a smaller heat capacity and thermal expansion are advantageous. It is desirable that a pressure member is in a form of a thin plate having a necessary strength.

For this reason, in a case of the sliding type, it is desirable to use a metal plate or a ceramic plate.

Next, a description will be given of a printer according to another exemplary embodiment. Unless otherwise specified, a structure of the printer according to another exemplary embodiment is similar to, if not the same as, the structure of the above-described printer.

Referring now to FIG. **8**, there is provided an enlarged view of the secondary transfer nip and a peripheral structure thereof in the printer according to another exemplary embodiment.

The printer of another exemplary embodiment uses a pressure plate **240** in a form of a plate member as a pressure member. The surface thereof over which the transfer-fixing belt **21** is laid is curved at a certain curvature.

The end portions of the upstream and downstream of the pressure plate **240** in the belt traveling direction of the transfer-fixing belt **21** are each biased by pressure springs against the intermediate transfer belt **11**.

According to the exemplary embodiment, the surface of the pressure plate **240** over which the transfer-fixing belt **21** is laid is curved at a certain curvature while the pressure plate **240** has a substantially flat shape.

Accordingly, though a portion thereof on which the belt is laid is curved at a certain curvature, a reduction in the size of the printer is achieved when compared with using a pressure roller having an equal curvature and an endless curved surface.

The radius of the curvature of the pressure plate **240** is greater than the radius of the curvature of the secondary transfer-drive roller **13**. The transfer-fixing belt **21** is gently laid along the pressure plate **240**.

When using the pressure plate **240** having such a moderate curvature, it is made possible to configure the traveling direction of the transfer-fixing belt **21** in the vicinity of the nip to be substantially perpendicular to the pressure direction, that is, a direction shown by an arrow C as shown in FIG. **8**.

Furthermore, it is made possible to easily extend the above-described minimum distance h up to a certain distance which may prevent the image irregularities caused by belt waving or wrinkles in the vicinity of the secondary transfer nip.

Referring now to FIG. **9**, there is provided a schematic diagram according to still another exemplary embodiment.

The printer according to still another exemplary embodiment uses an electromagnetic induction type heater as the heating unit **25** which heats the toner image on the transfer-fixing belt **21** from the front surface of the transfer-fixing belt **21**.

The heating unit **25** is disposed facing the front surface of the transfer-fixing belt **21**. A predetermined gap is provided between the heating unit **25** and the front surface of the transfer-fixing belt **21**.

The heating unit **25** includes coils **260** and a core **270** which holds the coils **260**. An intense electric field is formed between the heating unit **25** and the transfer-fixing belt **21**.

The belt base of the transfer-fixing belt **21** or another layer thereof is formed of metal so that the transfer-fixing belt **21** serves as an induction heating element which generates heat in the intense electric field formed by the heating unit **25**.

Accordingly, it is made possible for the transfer-fixing belt **21** to generate heat by itself without relying on radiation or heat conduction.

Referring now to FIG. **10**, there is provided a schematic diagram illustrating a printer according to still another exemplary embodiment.

The printer at least includes a photosensitive belt **8** and developing units **5**Y, **5**M, **5**C and **5**K for yellow, magenta, cyan and black, respectively, instead of a combination of process units for each color and intermediate transfer units.

The endless photosensitive belt **8** is stretchedly arranged between the primary transfer-drive roller **12** and the tension roller **14**, and endlessly travels in a counter-clockwise direction.

Above the front surface of the spanned photosensitive belt **8** traveling horizontally are arranged the developing units **5**Y, **5**M, **5**C and **5**K along the belt traveling direction.

The photosensitive belt **8** presses the transfer-fixing belt **21** at a position where the transfer-fixing belt **21** is laid on the pressure roller **24**. Accordingly, a primary transfer nip is formed.

Contact-separation mechanisms (not shown) each cause the developing units **5**Y, **5**M, **5**C and **5**K to come into contact with and to separate from the photosensitive belt **8**.

Furthermore, a contact-separation mechanism (not shown) causes the fixing pressure roller **29** which forms the transfer-fixing nip by coming into contact with the transfer-fixing belt **21** to come into contact with and separate from the transfer-fixing belt **21**.

When printing the four-color image, the above-described contact-separation mechanism causes the fixing pressure roller **29** to separate from the transfer-fixing belt **21**.

Subsequently, the optical writing unit **7** writes an electrostatic latent image on the front surface of the photosensitive belt **8**.

At a substantially same timing of writing, the above-described contact-separation mechanism causes the developing unit **5**Y among the developing units **5**Y, **5**M, **5**C and **5**K to come into contact with the photosensitive belt **8**.

The electrostatic latent image of yellow is developed by the developing unit **5**Y so that a yellow toner image is developed.

The yellow toner image is primarily transferred on the transfer-fixing belt **21** at the primary transfer nip where the photosensitive belt **8** and the transfer-fixing belt **21** come into contact with each other.

Similarly, toner images of magenta, cyan and black are formed on the photosensitive belt **8**. Subsequently, the toner images of magenta, cyan and black are sequentially overlaid on one another and are primarily transferred on the transfer-fixing belt **21**. Accordingly, a four-color toner image is formed on the transfer-fixing belt **21**.

When the primary transfer of the four-color toner image is finished, the contact-separation mechanism causes the fixing pressure roller **29** to come into contact with the transfer-fixing belt **21**. Accordingly, the transfer-fixing nip is formed.

Subsequently, the four-color toner image is secondarily transferred at once on the recording sheet P and is fixed in the transfer-fixing nip.

The descriptions have been given of the exemplary embodiments of the present invention applied to a printer using an electrophotographic method.

However, the present invention may be applied to an image forming apparatus which forms an image using a direct recording method disclosed in a related art, for example, Japanese Patent Laid-open Application Publication No. 2002-307737.

The direct recording method refers to a method in which a toner group dispersed in a form of a dot from a toner dispersion unit is directly adhered to an intermediate recording medium to create a pixel image.

Accordingly, a toner image is directly formed on a recording medium and an intermediate recording medium.

The printer according to the above-described exemplary embodiments uses the pressure roller **24** or the pressure plate **240** serving as a pressure member which causes the curved surface thereof curved at a certain curvature to come into contact with the transfer-fixing belt **21**.

According to the exemplary embodiments, an edge of the pressure member does not come into contact with the transfer-fixing roller **21**. Therefore, a damage to the transfer-fixing belt **21** caused by the edge touching the transfer-fixing belt **21** is reduced, if not prevented.

Furthermore, according the printer of the exemplary embodiments, the following condition is satisfied:

$$T_1 \sin\theta_1 + T_2 \sin\theta_2 < 2.5 \times S,$$

where θ_1 is an angle between the first virtual line segment L_1 and the third virtual line segment L_3; θ_2 is an angle between the second line segment L_2 and the third line segment L_3; S[cm^2] is an area of the secondary transfer nip; T_1[N] is a tension in the vicinity of the winding start point P_1 of the transfer-fixing belt **21** in the resting state; and T_2 [N] is a tension in the vicinity of the winding finish point P_2 of the transfer-fixing belt **21** in the resting state.

The first virtual line segment L_1 is a line segment extending from the winding start point P_1 to a center Pa of the virtual circle having the same curvature as that of the pressure roller.

P_1 is a start point of a belt winding of the transfer-fixing belt **21** which endlessly travels relative to the curved surface of the pressure member.

The third virtual line segment L_3 is a line segment extending from the center point Pc of the secondary transfer nip in the belt traveling direction to the center of the virtual circle.

The second virtual line segment L_2 is a line segment extending from the winding finish point P_2 to the center of the virtual circle.

P_2 is a finish point of a belt winding of the transfer-fixing belt **21** relative to the pressure member.

According to the exemplary embodiments, when the transfer-fixing belt **21** is laid on the curved surface of the pressure member, and the angles θ_1 and θ_2 are set to more than or equal to 0 degrees, it is possible to suppress the hollow defect in a print image.

In the printer according to the exemplary embodiments, the winding start point P_1 is positioned further upstream in the belt traveling direction of the transfer-fixing belt **21** than the transfer nip entrance point where the intermediate transfer belt **11** or the photosensitive belt **8** serving as an image carrier and the endlessly-traveling transfer-fixing belt **21** start to come into contact.

According to the exemplary embodiments, when compared with a case in which the winding start point P_1 is the transfer nip entrance point, image irregularities caused by belt waving or wrinkles in the vicinity of the secondary transfer nip entrance is reduced, if not prevented.

In the printer according to the exemplary embodiments, the winding finish point P_2 is positioned further downstream in the belt traveling direction of the transfer-fixing belt **21** than the transfer nip exit point where the intermediate transfer belt **11** or the photosensitive belt **8** and the endlessly-traveling transfer-fixing belt **21** start to separate from each other after passing the secondary transfer nip.

According to the exemplary embodiments, when compared with a case in which the winding finish point P_2 is the transfer nip finish point, image irregularities caused by belt waving or wrinkles in the vicinity of the secondary transfer nip exit is reduced, if not prevented.

In the printer according to the exemplary embodiments, the pressure plate **240** in the form of a plate member which curves at a certain curvature is used as a pressure member.

When compared with a pressure roller having the same curvature and an endless curved surface, reduction of the printer size is achieved.

In the printer according to the exemplary embodiments, a pressure member having a high stiffness is used.

Accordingly, a deformation of the pressure member caused by the stress due to wrinkles generated in the transfer-fixing belt **21** is reduced, if not prevented.

Therefore, the fluctuation of the secondary transfer nip pressure caused by the deformation of the pressure member is reduced, if not prevented.

Furthermore, elements and/or features of different exemplary embodiments may be combined with each other and/or substituted for each other within the scope of this disclosure and appended claims.

The number of constituent elements, locations, shapes and so forth of the constituent elements are not limited to any of the structure for performing the methodology illustrated in the drawings.

Still further, any one of the above-described and other exemplary features of the present invention may be embodied in the form of an apparatus, method, system, computer program and computer program product. For example, any of the aforementioned methods may be embodied in the form of a system or device, including, but not limited to, any of the structure for performing the methodology illustrated in the drawings.

One or more embodiments of the present invention may be conveniently implemented using a conventional general purpose digital computer programmed according to the teachings of the present specification, as will be apparent to those skilled in the computer art.

Appropriate software coding can readily be prepared by skilled programmers based on the teachings of the present disclosure, as will be apparent to those skilled in the software art.

One or more embodiments of the present invention may also be implemented by the preparation of application specific integrated circuits or by interconnecting an appropriate network of conventional component circuits, as will be readily apparent to those skilled in the art.

Any of the aforementioned methods may be embodied in the form of a system or device, including, but not limited to, any of the structure for performing the methodology illustrated in the drawings.

Furthermore, any of the aforementioned methods may be embodied in the form of a program. The program may be stored on a computer readable media and is adapted to perform any one of the aforementioned methods, when run on a computer device (a device including a processor).

The program may include computer executable instructions for carrying one or more of the steps above and/or more aspects of the invention.

Thus, the storage medium or computer readable medium, is adapted to store information and is adapted to interact with a data processing facility or computer device to perform the method of any of the above mentioned embodiments.

The storage medium may be a built-in medium installed inside a computer device main body or a removable medium arranged so that it can be separated from the computer device main body. Examples of a built-in medium include, but are not limited to, rewriteable non-volatile memories, such as ROMs and flash memories, and hard disks.

Examples of a removable medium include, but are not limited to, optical storage media such as CD-ROMs and DVDs; magneto-optical storage media, such as MOs; magnetism storage media, such as Floppy Disks™, cassette tapes, and removable hard disks; media with a built-in rewriteable non-volatile memory, such as memory cards; and media with a built-in ROM, such as ROM cassettes.

Example embodiments being thus described, it will be obvious that the same may be varied in many ways. Such exemplary variations are not to be regarded as a departure from the spirit and scope of the present invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

What is claimed is:

1. An image forming apparatus, comprising:

an image carrier configured to travel in an endless loop and including a surface configured to bear a visible image;

an endless transfer-fixing belt stretchedly arranged between at least two spanning members, wherein the endless transfer-fixing belt has a substantially flat front surface formed between the at least two spanning members, the endless transfer-fixing belt being configured to contact the image carrier via the front surface to form a transfer nip while contacting another member other than the image carrier to form a transfer-fixing nip;

a pressure member configured to press the front surface of the transfer-fixing belt to the image carrier while contacting a backside of the front surface of the transfer-fixing belt at the transfer nip, the pressure member being located between the at least two spanning members relative to the backside of the front surface of the transfer-fixing belt; and

a heater configured to heat the visible image;

the image carrier is further configured to transfer the visible image onto the front surface of the transfer-fixing belt at the transfer nip, and the transfer-fixing belt is further configured to transport the visible image to the transfer-fixing nip while heated by the heater, and to transfer and fix the visible image on a recording member; and

the transfer-fixing belt is stretchedly arranged such that the transfer-fixing belt travels in a direction substantially perpendicular to a pressure direction of the pressure member in a proximity of the transfer nip,

wherein the pressure member comprises a curved surface having a curvature and contacting the transfer-fixing belt, and

the image forming apparatus is further configured to satisfy the following relationship:

$$T_1 \sin\theta_1 + T_2 \sin\theta_2 < 2.5 \times S,$$

wherein θ_1 is an angle between a first virtual line segment L_1 extending from a winding start point P_1 of the transfer-fixing belt relative to the curved surface of the pressure member to a center of a virtual circle having the same curvature as that of the curved surface, the virtual circle being drawn along a curved direction of the curved surface, and a third virtual line segment L_3 extending from the center point of the transfer nip in a belt traveling direction of the transfer-fixing belt to the center of the virtual circle; θ_2 is an angle between a second line segment L_2 extending from a winding finish point P_2 of the transfer-fixing belt relative to the pressure member to the center of the virtual circle and the third line segment L_3; S is an area of the transfer nip; T_1 is a tension near the winding start point P_1 of the transfer-fixing belt in a resting state; and T_2 is a tension near the winding finish point P_2 of the transfer-fixing belt in the resting state.

2. The image forming apparatus according to claim **1**,

wherein the winding start point P_1 is disposed further upstream in the belt traveling direction of the transfer-fixing belt than a transfer nip entrance point where the image carrier and the transfer-fixing belt start contacting each other.

3. The image forming apparatus according to claim **1**,

wherein the winding finish point P_2 is disposed further downstream in the belt traveling direction of the transfer-fixing belt than a transfer nip exit point where the image carrier and the transfer-fixing belt start separating from each other after passing the transfer nip.

4. The image forming apparatus according to claim **1**, wherein the pressure member is a plate-shaped member curved at a curvature.

5. The image forming apparatus according to claim **1**, wherein the pressure member is formed of a material having a high stiffness.

6. The image forming apparatus according to claim **1**, wherein the at least two spanning members includes only two spanning members and one of the two spanning members forms one side of the transfer-fixing nip.

7. A method for forming an image with an image forming apparatus, the method comprising:

transferring a visible image to a surface of an image carrier;

forming a transfer nip by contacting the image carrier with a front surface of an endless transfer-fixing belt stretchedly arranged between at least two spanning members, wherein the front surface is a substantially flat surface formed between the at least two spanning members;

forming a transfer-fixing nip by contacting another member other than the image carrier with the front surface of the endless transfer-fixing belt;

pressing, via a pressure member, the front surface of the transfer-fixing belt to the image carrier in a pressure direction by contacting a backside of the front surface of the transfer-fixing belt at the transfer nip, the pressure member being located between the at least two spanning members relative to the backside of the front surface of the transfer-fixing belt;

transferring the visible image from the image carrier onto the front surface of the transfer-fixing belt at the transfer nip;

heating the visible image;

transporting the visible image to the transfer-fixing nip during the heating of the visible image;

transferring and fixing the visible image on a recording member; and

moving the transfer-fixing belt in a direction substantially perpendicular to the pressure direction at the transfer nip,

wherein the pressure member includes a curved surface having a curvature and contacting the transfer-fixing belt, and the image forming apparatus is configured to satisfy the following relationship:

$$T_1 \sin\theta_1 + T_2 \sin\theta_2 < 2.5 \times S,$$

wherein θ_1 is an angle between a first virtual line segment L_1 extending from a winding start point P_1 of the transfer-fixing belt relative to the curved surface of the pressure member to a center of a virtual circle having the same curvature as that of the curved surface, the virtual circle being drawn along a curved direction of the curved surface, and a third virtual line segment L_3 extending from the center point of the transfer nip in a belt traveling direction of the transfer-fixing belt to the center of the virtual circle; θ_2 is an angle between a second line segment L_2 extending from a winding finish point P_2 of the transfer-fixing belt relative to the pressure member to the center of the virtual circle and the third line segment L_3; S is an area of the transfer nip; T_1 is a tension near the winding start point P_1 of the transfer-fixing belt in a resting state; and T_2 is a tension near the winding finish point P_2 of the transfer-fixing belt in the resting state.

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